Books are not absolutely dead things, but do contain a potency of li
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vial the purest efficacy and extraction of that living intellect that br

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Librarian

ANESTHESIOLOGY

Second Edition

M DIGBY LEIGH, M D

Associate Professor of Surgery (Anesthesia)
University of Southern California
Director, Department of Anesthesia
Childrens Hospital of Los Angeles

M KATHLEEN BELTON, M D

Assistant Professor of Surgery (Anesthesia)
University of Southern California
Attending Anesthesiologist,
Childrens Hospital of Los Angeles

in collaboration with

GEORGE B LEWIS, JR , M D
EDWARD B SCOTT, M D

Assistant Attending Anesthesiologists,
Childrens Hospital of Los Angeles

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TO RALPH M. WATERS, M.D.
and WESLEY BOURNE, M.D.

whose teachings and guidance have contributed equally to the authors' basic knowledge for these studies on pediatric anesthesiology

FOREWORD

The importance of anaesthesia for children has not always been duly remarked Even now it is not always duly remembered by the anaesthetist The authors of this book show the way by pointing out clearly how drugs and as well the methods of their employment may be suited proportionately to the young as is done for the adult Leigh and Belton have given wings to practical thought in anaesthesia and have brought, for the first time into its serene and soothing atmosphere the strange element of Aristotelian simplicity Throughout the book there are numerous instances of lucidity in the description of vitally important features in pediatric anaesthesia

In this exiguous preamble a few only will be mentioned the very special attention one should pay to physiological processes in the infant, the importance of the "dead space", the need for particular care concerning carbon dioxide elimination during anaesthesia the constant vigilance which the anaesthetist must exercise about the state of the circulation that of the respiration, about oxygenation, blood replacement, and about the care of equipment These are a few examples of the many outward and visible signs of the inward and spiritual ardour of the authors —ardour neither headlong nor heedless

It is easy to portend certain intensifications for this treatise on pediatric anaesthesia as it begins its maiden voyage, like *The Ship Starting* of Walt Whitman [1]

[1] Whitman Walt *Leaves of Grass* Doubleday & Company Inc New York

Lo, the unbounded sea,
On its breast a ship starting, spreading all sails, carrying
even her moonsails,
The pennant is flying aloft as she speeds she speeds so stately
—below emulous waves press forward,
They surround the ship with shining curving motions and
foam

It is easy to see that as time goes on medicine will owe another debt, the value of which cannot be exaggerated, for our common heritage—the relief of pain—is being enhanced ineffably through the knowledge set forth in this book leaving great legacies of thought

Thought
Alone and its quick elements, Will, Passion,
Reason, Imagination, cannot die,
They are what that which they regard appears,
The stuff whence mutability can weave
All that it hath dominion o er, worlds, worms
Empires and superstitions What has thought
To do with time, or place, or circumstance?'
Shelley Hellas (Pisa, 1821)

The genius of Leigh, as it shines through, will stir the student of anaesthesia on to two at least of the first fruits of thought, namely, imagination and reason

WESLEY BOURNE

May 1948

PREFACE

This second edition of *Pediatric Anesthesiology* written a decade after the first edition has required complete rewriting The expansion in the scope of this edition represents the phenomenal growth in thought and action of this still very young specialty, pediatric anesthesiology

This book is intended primarily for those engaged in administering anesthesia to infants and children—physicians dentists osteopaths and nurses It is also intended for those who are responsible for the over all welfare of the infant or child—the pediatricians and the general practitioners It is intended for the surgeons who require maximum safety for their patients and maximum facility for their operative procedures It is intended for the nurses who have the responsibility of the preanesthetic and postanesthetic nursing care of the infant or child It is intended for the teachers of anatomy, pharmacology, physiology and biochemistry who carry the tremendous responsibility of teaching the basic principles of anesthesiology to medical students

This book is divided into four sections Section I describes the preanesthetic evaluation of the infant and child, containing a brief summary of a large number of the pediatric diseases and their effect upon the management of anesthesia In an effort to achieve a standardized form of diseases and to have this book serve as a ready reference, we have followed the nomenclature of the American Medical Association We must emphasize however, that this section is not intended to serve as a diagnostic text of childhood diseases but is an endeavor to form a link between the medical knowledge of the pediatrician and surgeon and that of the pediatric anesthesiologist

Section II covers the pharmacological effects of anesthetic agents, remarking on the basis upon which the selection of anesthetic agents is made There is a discussion of the anesthetic technics employed in pediatric anesthesiology Also included in this section is a description of anesthetic equipment, with emphasis placed on the necessity for conscientious preparation of such equipment

Section III describes our thoughts on the subject of preanesthetic medication and preparation of the infant and child, relating such preanesthetic preparation to the management of the patient during the operative and postoperative periods

Section IV outlines the management of the anesthesia for stated surgical procedures Again, we have adhered to the classification of operations established by the American Medical Association Also included in this section are chapters on the anesthetic management of the premature and newborn infant and on the postanesthetic management of the infant and child

Since the cooperation of many persons was an essential factor in the completion of this book, first, we must say that many times the combined number of hours spent by the authors in the assemblage of material for this edition of the book was spent by Joan Leigh in the composition organization, and innumerable retypings of the manuscript For her ability her fortitude her devotion, and her companionship, the authors are deeply grateful since these characteristics of Joan are truly responsible for each and every stage in the production of this book

We wish to thank the artists Miss J Tobian Mr Deryl Davis, Mr G W Gaw, Jr and Miss V Glass for their contributions and Mrs Sonja Binkhorst for the compilation of the bibliography

To the excellent professional staff of the Childrens Hospital of Los Angeles we express our sincere appreciation because without their co operation and exceptional pediatric and surgical experience and skill we would not have had the opportunity to witness the difficult operations and rare medical conditions discussed in this book In addition, we acknowledge the assistance received from the residents in anesthesiology at Childrens Hospital during the time that this book was written These residents contributed ideas from varied schools of learning such as County Hospital of Los Angeles (University of Southern California), White Memorial Hospital, Los Angeles (College of Medical Evangelists) Veterans Administration Hospital, Los Angeles, Naval Hospital of San Diego, Mayo Clinic, University of Colorado, Vancouver General Hospital, Van-

couver, Canada; Diploma Course, McGill University, Montreal, Canada, and the University of Tokyo, Japan. Deserving of special mention is Mr. J. J. Smits who, as administrator of Childrens Hospital, unhesitatingly supports the Department of Anesthesiology by providing the necessary facilities to carry on our work.

Copy for the frontispiece was supplied by the *Journal of the Medical Association of Georgia* (Vol. 48, October, 1959), and is reprinted with their permission.

We wish to thank the publisher, The Macmillan Company, for encouraging and unrelenting cooperation. Again, as in the first edition of this book, we are especially grateful to Miss Barbara Russell, production editor of the Medical Public Health Department of The Macmillan Company, for her capable editorial assistance and faithful attention to the details of production. Also offering valuable assistance in the course of the publication were Miss Artis Simonson and Miss Patricia Larson.

M. D. L.
M. K. B.

October, 1959

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PEDIATRIC ANESTHESIOLOGY

SECTION

I

EVALUATION OF THE PATIENT

The laudable ambition of every anesthesiologist to provide the best care for the child during the preanesthetic, anesthetic, and postanesthetic periods requires an evaluation and understanding of each patient. To achieve this the anesthesiologist reads the detailed history, physical examination, laboratory results, and treatment recorded on the hospital chart. Any characteristics which might influence the anesthetic management are examined during the preanesthetic visit to the patient.

In the more complex and unusual cases the anesthesiologist consults with the pediatrician or family doctor and with the surgeon

The surgeon and the anesthesiologist discuss the condition of the patient, the proposed operation and its probable length, blood requirements, posturing of the patient, and other factors necessary for the safety of the patient and for the facility of the surgeon

This coordinate understanding of the patient can be achieved only when the anesthesiologist has a knowledge of infant and childhood disorders We have included such a summary of diseases as a ready reference, using the classification of diseases and operations of the American Medical Association as outlined below

1 Body as a whole
    (A) Psyche
    (B) Generalized body disturbances
2 Integumentary system
3 Musculoskeletal system
4 Respiratory system
5 Cardiovascular system
6 Hemic and lymphatic systems
7 Digestive system
8 Urogenital system
9 Endocrine system
10 Nervous system
11 Organs of special sense (eye and ear)

CHAPTER 1

EVALUATION OF THE BODY AS A WHOLE

The *body as a whole* may be viewed from the mental or emotional aspects and the physical aspects that is the *psyche* and the *generalized body disturbances*

(A) PSYCHE

The pediatric anesthesiologist should have an understanding of the mental status of the patient since this will influence his approach to the patient, selection of premedication selection of anesthetic agent and technic and even the management of the immediate postanesthetic period The mental status of the patient is gauged from his normal mental development emotional disturbances and organic brain disorders

NORMAL MENTAL DEVELOPMENT

A knowledge of normal mental progress is necessary for comparison For example, by the end of the first year the infant shows a noticeable awareness of his environment by pointing his finger toward some bright or moving object By the end of the second year he has acquired a jargon and responds to command or gesture He sways rhythmically to music He may even seem to remember a previous unpleasant episode in an operating room By the end of the third year he can speak short sentences and understand simple explanations, thereby creating a better contact between himself and the anesthesiologist During the fourth year he asks innumerable questions and is interested in other people At five he talks more fluently, can tell a story, and knows his favorite television program At six the

child adds and subtracts small numbers From six to twelve he is adapting to school and community life and developing specific aptitudes (Fig 1) This course of development follows only if the infant or child has had a normal physical and mental growth

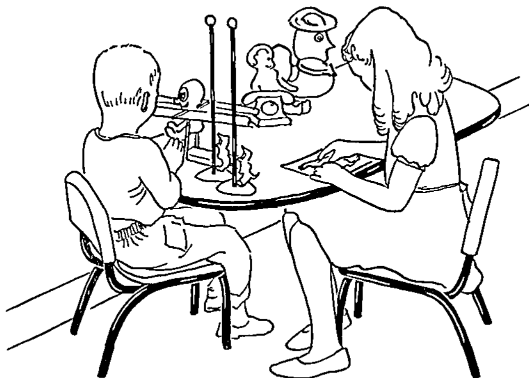


Fig 1 Children six to twelve years developing specific aptitudes

The parents pediatrician surgeon nurses, and anesthesiologist all play an important role in the psychic preparation of the patient for surgery The anesthesiologist should explain honestly and simply to the normal five-year-old child that he will be taken to the operating room on a carrier and that he will breathe into a little bag or balloon which will make him go to sleep, that he will awaken in his bed after the operation with a bandage over his eyes or with a cast on his arm whatever the case may be

EMOTIONAL DISTURBANCES

However there are children who have emotional disturbances and are uncooperative Some develop an alarming fear of the intravenous needle others are terrified of the mask on their faces others are afraid of a rectal instillation, and still others dread the postoperative nausea and vomiting produced by ether anesthesia In the majority of cases a phobia for anes-

them and surgery can be overcome by psychotherapy, an increased dosage of premedication, and a choice of agent and technic which is not so frightening to the particular child. Regardless of the basis for the emotional disturbance, a child in such a state is best controlled with more premedication than customary, for untreated apprehension multiplies with each visit to the operating room.

Children who have physical handicaps, such as deafness, blindness, or language difficulties, are tranquilized by either the written word, the spoken word, or an interpreter's explanation, whichever is suitable. To calm their fears, deaf children are frequently premedicated with a larger dosage of drugs or given basal anesthesia with rectal barbiturates.

ORGANIC BRAIN DISORDERS

Other children have definite organic brain disorders, either acute or chronic. Acute brain disorders may arise from general systemic infections, metabolic disorders, severe cranial injuries, or intracranial neoplasms. Chronic organic brain disorders include mongolism, microcephaly, hydrocephaly, chorea, spastic paraplegia, and mental retardation. Children who have acute or chronic brain disorders must be evaluated according to their mental status. The conscious, uncooperative patient generally requires increased amounts of preanesthetic sedatives, since the anesthesiologist seldom can apply successful psychotherapy. These sedatives also help to control the patient during the postanesthetic period.

In summary, the mental status of each patient should be classified as normal, emotionally disturbed, or disturbed by organic brain disorders.

(B) GENERALIZED BODY DISTURBANCES

Certain conditions or diseases have a widespread effect on the body. Among these are:

1. Prenatal influences
2. Infectious diseases
3. Intoxications
4. Trauma
5. Metabolism
6. Vitamins
7. New growths
8. Diseases of the reticuloendothelial system
9. Collagen diseases

PRENATAL INFLUENCES

Many anomalies in the newborn have origin in the first trimester of pregnancy Among these are mongolism, gargoylism, arachnodactyly (Marfan's disease), Klippel Feil syndrome monstrosity and prematurity Many of these are associated with other anomalies, and each patient must be considered in his entirety Most of these patients present problems for the anesthesiologist

Mongolism

This abnormality is characterized by underdevelopment of the brain, hypotonicity of the muscles small mouth slanting eyes, prominent epicanthic fold and shortened little fingers Such infants often have other anomalies notably tracheoesophageal fistula and imperforate anus More often they have a persistent atrioventricularis communis and it is this anomaly of the heart which causes their death following the neonatal period These infants, therefore, present a greater anesthetic risk as they grow older

Gargoylism (Hurler's Syndrome) (Lipochondrodystrophy)

Gargoylism is characterized by delayed closure of the fontanelles mental retardation, depression of the bridge of the nose short, thick neck due to the shortened vertebral bodies limitation of the extension of the joints, particularly the upper extremities resulting in clawlike hands kyphosis, corneal opacities macroglossia, hepatosplenomegaly, probably based on an alteration in the fat metabolism and congenital heart disease A patient with gargoylism often has respiratory obstruction during induction of an esthesia because of the narrowing of the nasal passages and the large tongue He also may be difficult to intubate because of the short neck limitation of movement of the joints and his large tongue One of our patients with gargoylism has had repeated operations for his inguinal hernia which tends to recur

Arachnodactyly (Marfan's Disease)

This disease is characterized by spiderlike digits slender, elongated fingers and toes long narrow skull high palate pointed ears, subluxated lenses and very little subcutaneous fat A patient with arachnodactyly often has deformities such as scoliosis, kyphosis malformation of the chest,

or congenital heart disease. The only child whom we have encountered with the disease was admitted to hospital for surgical correction of his scoliosis. Children with this malady are prone to respiratory disease, and it is recommended that respiratory depressants be omitted from the preanesthetic medication.

Klippel Feil Syndrome

This syndrome is characterized by complete fusion of the cervical vertebrae with marked limitation of movement. The condition is often associated with other abnormalities such as scoliosis, cervical rib, spina bifida and web neck. Intubation in patients with this syndrome may be difficult.

Monstrosity

Rarely the anesthesiologist encounters twin monsters who are anesthetized either for a study of the complex circulation under roentgenography, for which they must be kept still, or for the actual separation.

In our only experience the skulls were joined and the heads of both infants were acutely flexed. Each of these twins required independent anesthetization. They died from uncontrollable blood loss during separation of their conjoined brain tissue.

Prematurity

Fifty per cent of neonatal deaths occur in premature infants. Although the infant seldom dies in the operating room, ultimate recovery is uncertain because of the complications of prematurity and the disease for which surgery is performed.

On the preanesthetic visit the anesthesiologist should be able to determine the degree of immaturity of the infant. The arbitrary definition of a premature newborn infant is one weighing 2500 gm (5 lb 8 oz) or less. As a rule, the smaller the infant, the greater is the degree of immaturity. Other methods used for classifying the premature infant are a crown heel length of less than 47 cm, a head circumference of less than 33 cm and a thorax circumference of less than 30 cm. However, the weight and size alone are not satisfactory criteria for the preanesthetic evaluation, and there are many other characteristics which measure the hazards of immaturity from the point of view of anesthesiology.

Before visiting the premature nursery the anesthesiologist should put on a cap and a mask, scrub his hands, and then dress in a clean gown in

order to prevent infecting the premature infant Infections may be fatal in the premature who fails to gain immune bodies from the mother and lacks the ability to develop them

The premature infant usually lies in an incubator where the temperature is kept between 26° and 32° C for the very small infant, and from 23 8° to 26° C for the infant close to 2500 gm Humidity is between 55 and 60 per cent and the oxygen is limited to a maximum of 40 per cent The infant generally is lying on his side to facilitate the escape of oral secretions His skin is a dark red color in contrast to the bright red color of the full term infant whose arterial blood is better oxygenated The head of the premature infant seems large the eyes prominent and the skin somewhat wrinkled because he has very little subcutaneous fat He is inactive most of the time

Many premature infants are jaundiced at birth There is a tendency to form edema around the buttocks and the lower extremities Some of these infants show a sclerema or hardening of the tissues in the region of the buttocks Sclerema is always a grave prognostic sign and warns the anesthesiologist of a probable fatal outcome postoperatively

The ears of the premature are somewhat flabby, the fontanelles are small and often only the anterior fontanelle is open The cranial bones are in contact at the sutures The greater the prematurity the more constant is this finding About the middle of the second week after birth because of the rapid growth of the brain the suture lines separate and the fontanelles become larger because the bony growth cannot keep up with the brain growth

When judging prematurity Parmelee places considerable emphasis on the breasts The breasts of the full-term infant of both sexes swell at birth and have a discharge but this characteristic is not present in the premature

The premature is poikilothermic This magnified response to his environmental temperature makes the avoidance of undue heat (Fig 2) and cold (Fig 3) mandatory Since he readily develops a subnormal temperature in the ordinary atmosphere he should not be removed from the incubator by the anesthesiologist for his examination The subnormal temperature may be caused by heat loss from a relatively large body surface by a paucity of insulating subcutaneous fat and by a low heat production from inactivity and absence of shivering The inability of the premature to stabilize his body temperature is due to the immaturity of the temperature regulating mechanism

The greater the degree of immaturity, the more difficult it is for the infant to suck or swallow. Food is readily aspirated into the lungs since the gag reflex is weak. Since nutrition is poorly maintained the very immature infant must be fed through an esophageal catheter.

It is believed that the premature infant has a poor storage of calcium, phosphorus, vitamin D and vitamin K. To restore the vitamin K deficiency the premature is often given 5 mg of vitamin K intramuscularly daily in preparation for anesthesia and surgery.

Other evidence of prematurity can be obtained from x ray of the long bones and from the presence of the various ossification centers.

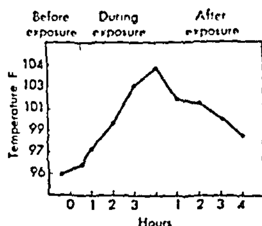


Fig. 2 Premature infant's response to warmed atmosphere (Smith C A. *The Physiology of the Newborn Infant* 3rd ed Charles C Thomas Publisher Springfield Ill 1959)

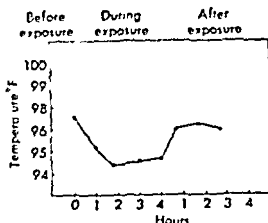


Fig 3 Premature infant's response to cooled atmosphere (Smith C A *The Physiology of the Newborn Infant* 3rd ed Charles C Thomas Publisher Springfield Ill 1959)

Estimation of the efficiency of the respiratory system is the greatest concern of the anesthesiologist, for the lungs may have immature alveoli and numerous solid nests of cells. Many of the inflatable alveoli are rudimentary with few branches and small surface area, and have no pulmonary capillaries. It is clear, therefore that the premature infant has a lung with an extremely small functional respiratory surface. In addition there is a very meager amount of supporting tissue so that collapse and overdilatation can occur even more readily than in the normal, full term newborn. There is even greater immaturity of the cartilages of the trachea and bronchi than in the full term infant and these air passages are very short, narrow and thin walled with little fibrous or elastic tissue. The weak respirations are diaphragmatic, and the bony thorax tends to collapse on inspiration although this is not a prominent feature in the quietly sleeping infant. Most premature infants breathe irregularly and at birth may

have typical Biot s respiration characterized by a sudden onset of respiration which continues for a short time and then stops suddenly later commencing spontaneously and then proceeding through the same cycle The irregularity of breathing can be changed to regular rhythm by breathing 3 4 per cent carbon dioxide In the full term infant, one half of this concentration will produce the same result An x-ray film of the thorax may also contribute to the preanesthetic evaluation of respiration In such a film, residual patches of atelectasis, hyaline membrane pneumothorax or elevation of the diaphragm may be detected before anesthesia The surgeon might hesitate to open one side of the thorax of an infant if even a mild pneumothorax were present on the opposite side

On account of torpor, irregularity of respiration and the over-all immaturity of the respiratory system no sedatives are given to premature infants Because of the lack of secretions no belladonna derivatives are needed

The premature infant usually has a very low arterial and venous pressure Often the systolic pressure is only 60 mm of mercury The infant has however a relatively large heart, being over 50 per cent of the chest diameter in the anteroposterior films of the thorax The capillaries are poorly developed The infant may have a high hemoglobin at birth which falls to a low level during the first three months An infant weighing less than 1500 gm may show 7 to 8 gm of hemoglobin and a red blood cell count of 2 000,000 to 3 000 000 at the end of 3 months This severe anemia is due to the omission of iron storage in the infant normally occurring during the last trimester of pregnancy when iron is transferred from the mother to the fetus There is also an increased destruction of red blood cells and an immaturity of the bone marrow Red blood cell production cannot keep up with the tremendous demand in a rapidly growing infant or with the increased destruction There is a decrease in the blood proteins Albumin is 3 55 gm and globulin is very low—0 01 gm—in the premature weighing 1500 gm or lower Vitamin K deficiency causes hypoprothrombinemia thereby increasing the bleeding tendency In addition, there is an increased fragility of blood vessels and an increased permeability of capillaries the latter probably the result of hypoxia

Little is known of the digestive system except that there is a low gastric acidity

The kidneys are affected by the low blood pressure perhaps explaining a very low glomerular filtration rate There is an inability to concentrate the urine as well as difficulty in the excretion of sodium and chloride Dur-

ing anesthesia fluids and electrolytes should be either restricted or omitted

The Moro reflex is incomplete and when an attempt is made to elicit it there is extension of the arms and abduction of the fingers but the arms are not brought forward following extension Coarse tremors of the extremities are seen frequently

The premature infant is prone to retrolental fibroplasia a disease characterized by the formation of a fibroplastic membrane covering the posterior aspect of the lens of the eye This is especially true if the infant has been in an oxygen atmosphere higher than 50 per cent

Strabismus is seen quite frequently in this particular group of infants

It must be remembered by the anesthesiologist that the premature infant generally does not gain the normal physical development for his age group until he is about two years of age

INFECTIOUS DISEASES

Since newborn infants possess extremely little resistance to infection every known precaution should be taken in the preparation for anesthesia Newborn infants may develop a bacteremia and die very suddenly with the only evidence of infection being a rapid pulse and a positive blood culture

Young infants seldom develop the well known infectious childhood diseases as they usually inherit a certain amount of immunity to these diseases from their mothers Older children, however, are subject to the following infectious diseases

Viral Diseases

Diseases caused by viruses include roseola infantum measles rubella (German measles), chickenpox, smallpox, mumps, infectious hepatitis, herpes simplex infectious mononucleosis, yellow fever, and dengue Infants or children with any of the following viral diseases may present anesthetic problems

Measles It is not unusual to have an appendectomy performed while a patient has measles Isolation technic should be observed whenever the anesthesiologist is in contact with the patient Certain complications of measles demand attention, such as a tracheobronchitis or a bronchial pneumonia and more rarely an encephalitis manifested by an increasing lethargy or even convulsions

Mumps A patient with mumps has a marked tenderness in the region of the salivary glands Therefore premedication should include adequate

pain relieving drugs and the belladonna alkaloids The latter should decrease the pain caused by excessive salivary secretion In some cases of mumps there will be central nervous system pancreatic testicular, or ovarian involvement In moving the patient it is advisable, if an orchitis is present to have the scrotum suspended in a sling

Infectious Hepatitis Differing from homologous serum hepatitis in that the onset is abrupt and with fever, infectious hepatitis is usually transmitted by the oral route These patients have impaired liver function and may *have a low prothrombin level with a hemorrhagic tendency requiring* transfusions Acute yellow atrophy with fatal outcome is rare

Herpes Simplex This is normally characterized by a herpetic gingivostomatitis which is painful although the virus may attack the vulva eyes meninges nose, and skin It is transmitted by direct contact The stomatitis type often interferes with nutrition because of the pain and often these patients require analgesics before meals In the skin variety opiates should be omitted for they tend to increase the irritation prompting the children to scratch The anesthesiologist should employ utmost caution to avoid contact with the lesion and to avoid transmission to other patients

Infectious Mononucleosis This is not a *very contagious disease and* is rare in infancy The child afflicted with the disease has malaise sore throat enlarged lymph nodes splenomegaly and sometimes an infective myocarditis

Bacterial Diseases

Included in this category are the streptococcal diseases such as scarlet *fever pneumococcal diseases staphylococcal diseases* pertussis, diphtheria tetanus gas gangrene salmonellosis (typhoid and paratyphoid) shigellosis (bacillary dysentery) gonorrhea tularemia plague cholera and brucellosis Of particular concern to the anesthesiologist are the following

Streptococcal Diseases These diseases are characterized by sore throat high temperature and a rash The illness varies from a mild attack to a very severe one In very young children, a septicemia may occur with its accompanying myocarditis Penicillin has helped immeasurably to eliminate the complications of these diseases although in the unrecognized case the surgical wound may break down

Pneumococcal Diseases These diseases usually affect the respiratory tract The patient has a high fever malaise and rhinitis Children under the age of six often have a peribronchial pneumonia while older children may manifest a typical lobar pneumonia A rare complication is meningitis

On occasion these patients have pneumococcal peritonitis giving the signs and symptoms of acute appendicitis. If there is much lung involvement there may be distention of the stomach. Opiates or opiate-like drugs should be used in the premedication in order to decrease the respiratory rate although it is unwise to depress the respiration too much for fear of hypoxia. Small dosages of belladonna drugs are adequate to prevent secretions from obstructing the respiratory tract. In anesthetizing children with pneumonia we employ the endotracheal technic, for we believe that it provides better control of oxygenation and carbon dioxide elimination. Reduction of the body temperature at least to normal reduces the work of the heart.

Staphylococcal Diseases. These diseases may cause furunculosis, impetigo, osteomyelitis or severe food poisoning with marked vomiting and diarrhea. Occasionally staphylococcal pneumonia or septicemia may occur. Unfortunately many of these bacteria are resistant to antibiotics, and in the chronic state of multiple lung or skin abscesses the patients have a markedly reduced cardiac reserve. They usually are severely debilitated. Some years ago we attempted to aspirate the tracheobronchial tree of a patient with multiple lung abscesses. Although the patient had been chronically ill on the ward for some months, the slight breath holding at the time of the insertion of the laryngoscope and the tracheal catheter caused an abrupt demise of the patient. This was probably due to a brief period of hypoxia in a patient with a reduced cardiac reserve.

Pertussis. Patients with this disease have tenacious mucus with paroxysmal bouts of coughing and vomiting. Complications may be due to pneumonia, atelectasis and emphysema, but on occasions convulsions may be caused by the cerebral anoxia occurring during the paroxysmal coughing. The high venous pressure produced by the coughing may give rise to hemorrhages in the eyes or the nose. Young infants with their incompletely developed respiratory system, small reservoir of oxygen and reduced muscular strength show alarming exhaustion following the more severe bouts of coughing. Opiates may be of value in the preanesthetic medication to reduce the number and severity of coughing spells.

Diphtheria. A patient with diphtheria is often gravely ill. The membrane may form in the throat and spread down into the larynx and trachea causing obstruction to respiration with cyanosis. Other complications of diphtheria are neuritis which may affect the muscles of the pharynx, the palate or the eye; bronchopneumonia may also occur.

But the greatest danger stems from the exotoxin which affects the heart

From the viewpoint of anesthesia, a patient with diphtheria should have a continuous electrocardiogram during surgery so that T wave changes or interferences with the conduction mechanism, such as atrioventricular block may be observed

Extreme care must be exercised in the handling of a patient with diphtheria should surgery be mandatory Sedatives should be omitted because of the danger of respiratory obstruction If prolonged surgery is necessary a tracheostomy is advisable, and the anesthesia should be administered through the tracheostomy tube Each patient should be regarded as having myocarditis As a rule however, the pediatrician believes that this type of myocarditis should not be treated with digitalis for the stimulation of the weakened myocardium with digitalis can be fatal

Tetanus Most infants and children are immunized against tetanus by active immunization with toxoid although infection can occur in the newborn by transmission through the umbilical cord A patient with severe tetanus may require anesthesia for surgery involving the original portal of entry of the *Clostridium tetani* Such a patient requires minimal handling larger than normal dosages of premedication to control the tetanic convulsions frequent aspiration of the pharynx and at times a tracheostomy to facilitate tracheal aspiration

Anesthesiologists often are requested to consult on the control of tetanic convulsions Barbiturates and muscle relaxants are most useful in abolishing the convulsions and loosening taut muscles Usually the accompanying respiratory depression is overcome by placing the patient in a respirator A tracheostomy is also frequently done to allow adequate suction of accumulated secretions and to prevent atelectasis

Gas Gangrene A patient may develop gas gangrene by being infected with *Clostridium welchii* Sometimes such a patient has not had any violent trauma which would warn the physician to give antitoxin or toxoid A patient with gas gangrene is often seriously ill and has an elevated temperature and rapid pulse Milder dosages of premedication and body cooling are indicated In addition an anesthetic agent which is least depressing to the myocardium should be chosen

Salmonellosis This includes the paratyphoid and typhoid diseases Typhoid may be very severe in children and cause anorexia vomiting abdominal distention diarrhea bradycardia and splenomegaly In infants a septicemia may occur with convulsions On occasions delirium and high fever complicate the disease Fortunately perforation and hemorrhage of the intestine are rare in infants and children The anesthesiologist should

bear in mind that sometimes these patients have pulmonary complications and that their feces may be highly infective.

Shigellosis This disease generally produces a high fever, vomiting, bloody diarrhea, colic, and even shock. In addition, because of the generalized abdominal tenderness and some rigidity, it may be easily confused with appendicitis. Fluid and electrolyte balance must be restored quickly with parenteral fluids, for the fluid and base loss through the stool, unless replaced, increases the dangers of anesthesia. Blood loss, too, may be severe enough to cause anemia.

Rickettsial Diseases

In this group are included typhus, Rocky Mountain spotted fever, Q fever and rickettsialpox. Most of these diseases are not widespread in their occurrence except perhaps typhus, which is endemic in various parts of the world. However, bronchopneumonia, renal insufficiency, or a myocarditis may occur. If a myocarditis is suspected, monitoring of the heart with an electrocardiogram during surgery is advised. Digitalis must be used with extreme caution.

Fungal Diseases

Coccidioidomycosis (Valley Fever) The complications of this disease are respiratory and may even resemble tuberculosis.

Actinomycosis This is due to infection by *Actinomyces bovis*. There are three different types: cervicofacial, in which there is a hard swelling in the jaw and neck with a final breakdown into a chronic sinus, the abdominal type which may follow an appendectomy and also cause a chronically draining sinus, and finally, the thoracic type which resembles chronic pulmonary tuberculosis. Many patients with actinomycosis become severely debilitated and have typical myocarditis caused by chronic infection or malnutrition.

Histoplasmosis This is caused by *Histoplasma capsulatum*. The severe systemic type will produce malaise, weight loss, mild diarrhea, pyrexia and anemia. Like the severe form of actinomycosis, death may occur within a few months from the onset of the disease.

Spirochetal Diseases

Syphilis This is usually the congenital type in infants and children, generally due to direct infection from the placenta. The early type of congenital lues manifests itself before the sixth week by snuffles, mucopuru-

lent nasal discharge, skin rash anemia osteochondritis, hepatomegaly with jaundice, splenomegaly and retinitis which later may lead to optic atrophy Late congenital lues does not show any signs until after the third month of life Such an infant has a saddle nose and saber shins The deciduous teeth are normal but the permanent teeth may be peg shaped (Hutchinsonian) There are rhagades at the corner of the mouth and nose and an interstitial keratitis

Spirochetal Jaundice Generally transmitted by rats, it is characterized by high fever jaundice, a rash, and meningeal involvement The kidneys may become involved with a very severe reduction in urinary output

Animal Parasitic Diseases

Oxyuriasis (Pinworms) The disease is very widespread in children There is pruritis ani, and sometimes abdominal pain caused by involvement of the appendix We have seen pinworms frequently in the removed appendix

Ascariasis (Roundworms) Occasionally there is colicky pain or respiratory symptoms due to the presence of the larval stage in the lungs On the whole such a patient shows neither signs nor symptoms

Ancylostomiasis (Hookworms) With this malady the child has anorexia pallor malaise and hypochromic microcytic anemia An infested patient should be treated with iron and transfusions before anesthesia since the anemia often is severe

Trichinosis (Tapeworms) This may be due to invasion by beef pork, or fish tapeworm It may result in diarrhea, fever, and anemia

Protozoan Diseases

Malaria This disease is the major cause of death throughout the world It causes a high fever and may produce convulsions in young children but the attacks are not as regular as in adults Diarrhea vomiting and splenomegaly are generally present Anemia is often severe Before anesthesia such a patient requires intravenous fluids and therapy for the anemia A continuous recording rectal thermometer should be inserted and any hyperthermia should be corrected by placing the patient on a mattress through which ice water circulates

Amebiasis Caused by *Endamoeba histolytica* it is characterized by recurrent bouts of diarrhea The invading organism may settle in the liver Parenteral fluids should be given before anesthesia to restore the fluid and

[illegible] spread rapidly from patient to patient

INTOXICATIONS

Allergies

Most allergic children have a strong family history. An allergy may be manifested in infancy by eczema, in childhood by hay fever, and in adult life by asthma. Since allergy is such a long chronic disorder, patients often become introspective and hypochondriac.

It is most important from an anesthesiologic standpoint to elicit an existing allergic history, for so many premedicant and anesthetic drugs have an adverse effect on asthmatic or allergic patients. It is often wise to include an antihistaminic drug in the premedication whenever a patient has moderate to marked allergic manifestations.

Eczema. Many of these infants are now treated with cortisone, and the anesthesiologist should be alert for a history of such therapy, as in any patient with allergy.

Allergic Rhinitis (Hay Fever). This does not affect children until about the third year of life. The child with the disease often has a red nose and partial obstruction to breathing. Later, polyps may form in the nose. On occasion these polyps may block a nasotracheal tube. Antihistaminics should be used in the premedication and occasionally 0.25 per cent phenylephrine hydrochloride (Neo-synephrine) should be applied to the nasal passages prior to anesthesia.

Asthma. A patient with asthma generally gives a history of allergic rhinitis. The classic case shows nasal congestion, a persistent and easily aroused cough, prolonged difficult exhalation, hyperdistention of the bronchioles and alveolar ducts with adjacent areas of atelectasis. In more chronic cases there are hypertrophy of the right heart, pulmonary hypertension, carbon dioxide elevation, and compensatory chloride depression. Pulmonary function tests show increased timed vital capacity and functional residual capacity.

Inhalation therapy with bronchodilators such as isopropylarterenol hydrochloride (Isuprel) improves respiratory function in many instances and should be carried out for a few weeks prior to elective surgery. Blood pressures should be recorded during Isuprel treatment to detect early the hypotensive effects of overdosage of Isuprel. The asthmatic patient should be

premedicated with an antihistaminic and atropine Administration of a tranquilizing antihistaminic for a few days prior to surgery, 2 to 4 mg per kg of body weight every 24 hours divided into 4 dosages may avoid an asthmatic attack Ether anesthesia appears to reduce or prevent asthmatic attacks postoperatively We have occasionally used barbiturates together with atropine for premedication and have yet to see a severe attack of asthma before, during or after anesthesia by this method

Serum Sickness This has become a frequent complaint since the widespread use of penicillin It is ordinarily manifested by an urticarial skin eruption occurring about a week following the injection of penicillin In instances of repeated surgery, as in patients with burns, small dosages of antihistaminics for preanesthetic medication are superior to opiates which intensify the annoying itchiness of the urticaria

Drugs

Often it is reported that patients have had abnormal responses to drugs For example profound effects have been reported from small dosages of barbiturates or opiates or marked nausea from opiates or opiate like drugs Most of these stories are exaggerated but the anesthesiologist cannot ignore a history of drug idiosyncrasy and after careful questioning should omit the use of any drugs to which the patient reputedly has shown an unusual reaction

Icterus (Jaundice)

Physiological icterus is common in the premature at birth and in the normal full term infant from two to seven days after birth Pathological icterus is encountered in obstruction of the bile ducts erythroblastosis, syphilis, or sepsis

Jaundiced patients often have depressed respiration and a slow heartbeat probably due to the accumulation of bile salts in the blood No narcotic or barbiturate sedation should be given in the premedication and the anesthesiologist should bear in mind that during the administration of the anesthesia cardiac arrest can occur almost without warning Realizing that these patients have a narrow safety margin the anesthesiologist might select endotracheal technic so that the ventilation of the lungs can always be under control and the patient can be kept in a lighter plane of anesthesia for dosages of anesthetic agents which would not affect robust children might be fatal in this group

Edema

Generalized edema is usually of cardiovascular, hepatic, renal or hypoproteinemic origin, and draws the attention of the anesthesiologist to impaired function of these systems

TRAUMA

Trauma in General

A large number of infants and children are injured severely each year Severe lacerations severed blood vessels bone fractures, skull fractures, fractured backs fractured ribs, and ruptured viscera are seen frequently Blood loss may be copious and the patient may be in shock Severe skull fractures may produce unconsciousness Fractured ribs may interfere with respiration They can also cause marked pain, and it may be advisable to relieve this pain by intercostal nerve blocks In severe crushing injuries of the thorax in which several ribs are fractured positive pressure breathing may be required

Injuries have to be evaluated individually If the trauma is of many hours' duration and shock is present, blood replacement must be given gradually for in these instances the myocardium is often weakened by hypoxia and cannot handle large amounts of blood quickly without severe cardiac dilatation and subsequent death Shock conditions from blood loss if prolonged may give rise to lower nephron nephrosis

Patients unconscious from intracranial injuries should receive no sedative

Blast Injuries

Blast injury may produce numerous small hemorrhages in the lung and a tendency to pulmonary edema If it is necessary to anesthetize a patient who has been subjected to a blast injury, the anesthesiologist should reduce the depressant in the premedication to a minimum and select a technic of anesthesia which will enable the use of positive pressure breathing

Burns

Burns are one of the commonest severe traumatic injuries in children The major disaster is general body trauma, measurable mainly by the surface extent and partly by depth A rough estimate of this may be made

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longed time Because of frequent exposure to radiation, the anesthesiologist now wears a detector badge He should not exceed exposure to more than 300 milliroentgens per week

METABOLISM

General Nutrition

During the preanesthetic visit the anesthesiologist should evaluate the patient from the standpoint of his general appearance The pale, asthenic child with little subcutaneous fat and a transparent skin does not withstand the anesthetic or surgical stress as well as the vigorous healthy, sthenic child

Fluid and Electrolyte Balance

In pediatric patients, the maintenance or restoration of normal fluid and electrolyte balance often demands priority over the operation An infant or child within a few hours can either lose or accumulate large quantities of water and salts, enhancing the risk of anesthesia and surgery For example, a dehydrated patient with his consequent reduced blood volume may go quickly into shock during anesthesia In the infant or ill patient the regulatory mechanism of the kidney, adrenal cortex, pituitary glands and parathyroid do not function efficiently in controlling the internal environment

The history, physical examination and laboratory findings offer clinical guidance to fluid and electrolyte imbalance, which can be determined accurately only by extracellular fluid changes and the only extracellular fluid readily accessible to the clinician is the blood There may be the following imbalances

1 Extracellular fluid volume excess or deficit
2 Extracellular fluid total salt concentration excess or deficit
3 Extracellular fluid compositional imbalances such as potassium excess or deficit calcium excess or deficit or more important to the anesthesiologist the acid base imbalances The latter include metabolic acidosis and alkalosis and respiratory acidosis and alkalosis

I Volume Imbalances

A Extracellular Fluid Volume Excess

Clinical Causes

1 Parenteral administration of excessive sodium chloride solution

by the rule of 9 in older children the head is 9 per cent, front of trunk 18 per cent back of trunk 18 per cent, each lower limb 18 per cent, each upper limb 9 per cent in infants, allowance must be made for the relatively large head

The early response of the tissue to the burn is a considerable loss of plasma into the burned area, hemoconcentration, oliguria, reduced blood volume, low blood pressure, and a rapid pulse indicative of low cardiac output

Reduction of renal function one of the most serious complications of burns, is detected by oliguria hemoglobinuria elevation in serum non protein nitrogen, sodium, and potassium and increase in body weight The elevated potassium results in the hyperkalemic patient who is susceptible to hypotension from anesthetic agents A subsequent diuresis lowers the serum sodium and potassium and decreases the body weight The lowered serum sodium and potassium, in turn decrease intestinal peristalsis and muscle power, with consequent dilatation of the stomach and intestine, such dilatation may be reduced by a nasogastric tube Gross fluid and electrolyte imbalance can be fatal during the early stages of a burn and must be corrected insofar as possible before anesthesia

Another complication infection of a large burn wound may give rise to a septicemia, detectable by rapid pulse, elevated temperature, low blood pressure and possibly a positive blood culture This infection may cause a serious myocarditis

Respiratory complications may be laryngeal or pulmonary edema from inhalation of fumes at the time of the burn although the pulmonary edema also could be caused by excess fluid administration Burns of the thorax may limit expansion of the chest thereby reducing compliance

Other grave signs in the burned patient are lethargy, mental confusion, coma and occasionally decerebrate rigidity

Radiation Injuries

Radiation injuries are due to alpha beta gamma, or neutron radiation The latter three are more penetrating and may cause a cessation of mytosis of the cells or a swelling fibrosis and hyalinization of the stroma They may also cause thrombosis and fibrosis of the blood vessels The acute radiation syndrome may follow one of two courses first the patient has nausea vomiting prostration mild diarrhea leukopenia anemia, and fever and death occurs five to ten days after exposure, and second the patient has pallor weakness and cachexia and death occurs after a pro-

potassium	5 mEq
calcium	7
chloride	114

Butler's Solution
each liter of which contains

sodium	40 mEq
potassium	35
chloride	40
lactate	20
phosphate	50
(and 5% dextrose)	

Solution for the Neonate
each liter of which contains

sodium	25 mEq
potassium	20
magnesium	3
chloride	22
lactate	23
phosphate	3

In the above solution for the infant up to the end of the first month of life, the concentrations of electrolytes have been decreased because of the physiological immaturity of the infant's kidney with its inability to concentrate

Not any of these homeolytic solutions are employed if there is evidence of kidney adrenal, pituitary, or parathyroid dysfunction In fact an initial hydrating solution of normal saline (360 ml per sq meter of body surface) is given, and voiding should commence within 45 minutes Homeolytic solutions are often administered according to body surface area, which is calculated according to the nomogram in Figure 4 In the severely dehydrated patient, the daily dosage is 3000 ml per sq meter of body surface In the moderately dehydrated patient, it is 2400 ml per sq meter of body surface, and the daily maintenance dosage is 1500 ml per sq meter of body surface

II Concentration Imbalances

A Extracellular Fluid Total Salt Concentration Excess (Hypernatremia)

Clinical Causes

1 Decreased water intake
2 Excessive administration of electrolytes
3 Loss of fluid into burned areas

Clinical Findings

1 Hoarseness
2 Shortness of breath
3 Rapid weight gain
4 Distention of the peripheral veins
5 Moist rales in the lungs
6 Edema of the tissues observed during surgery
7 Blood volume increase
8 Increased tissue fluid volume

Laboratory Findings

1 Hematocrit hemoglobin and red blood cell count below normal

Treatment

Withhold fluids

Comment

These patients are prone to pulmonary complications postoperatively

B Extracellular Fluid Volume Deficit (Dehydration)

Clinical Causes

1 Reduction in intake of fluid
2 Acute loss of fluid
3 Vomiting
4 Diarrhea
5 Fistulous drainage

Clinical Findings

1 Stupor
2 Depressed fontanelles
3 Sunken eyeballs
4 Increased body temperature
5 Loss of body weight—*in the infant or small child* a weight loss of more than 10 per cent indicates a severe fluid deficit
6 Dry skin
7 Lost elasticity of the skin
8 Depressed gastrointestinal activity

Laboratory Findings

1 Blood volume decreased
2 Elevated hemoglobin hematocrit and red blood cell count
3 Oliguria
4 *High specific gravity of the urine*
5 Chloride absent from the urine

Treatment

Homeolytic solutions

Ringer s Hypotonic NaCl 0 6%
each liter of which contains

sodium 102 mEq

5 Renal depression (oliguria)
6 Rapid heart rate

Laboratory Findings

1 Plasma sodium above 140 mEq/liter
2 Plasma chlorides plus bicarbonate ions above 130 mEq/liter

Treatment

Administer 5% dextrose in water

B Extracellular Fluid Total Salt Concentration Deficit (Water Intoxication) (Hyponatremia)

Clinical Causes

1 Excessive drinking of water or excessive parenteral fluids without adequate renal excretion

Clinical Findings

1 Gain in weight
2 Warm moist flushed skin
3 Blood pressure normal or raised
4 Pulse rate normal
5 Veins distended
6 Loss of attention confusion staring aphasia
7 Increased intracranial pressure
8 Convulsions or unconsciousness
9 Nausea and emesis
10 Renal depression
11 Interstitial edema of lungs and hyperventilation

Laboratory Findings

1 Intracellular fluid volume excess
2 Plasma protein hemoglobin hematocrit and red blood cell count low
3 Plasma sodium (125–133 mEq/liter) chlorides potassium and nonprotein nitrogen (if no anuria) low
4 Plasma chlorides plus bicarbonate ions less than 120 mEq/liter
5 Specific gravity of urine low

Treatment

1 Restrict water intake
2 Administer 3% sodium chloride solution (should be administered slowly)

Example

20 kg child with 125 mEq of Na (140 mEq/liter is normal)
Amount of water = 60% of 20 kg which is 12 kg or 12 liters of water
Each liter of body water has a deficit of 140 − 125 = 15 mEq
Therefore, 12 liters of body water have a deficit of 12 × 15 mEq = 180 mEq
3% sodium chloride has 51 mEq of Na/100 ml
Therefore, to supply 180 mEq

$\frac{180}{51} \times 100 = 350$ ml of 3% sodium chloride

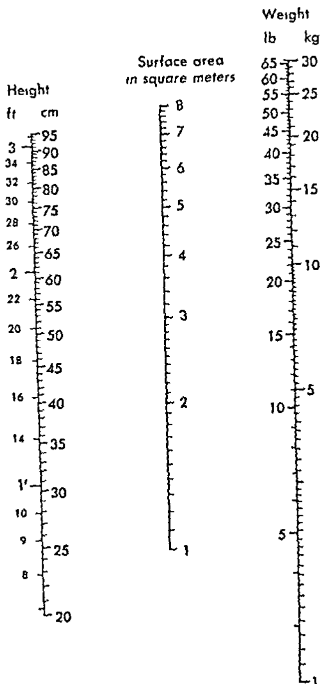


Fig 4 Nomogram for calculating infant's surface area from height and weight—line drawn through height and weight of infant bisects surface area (Courtesy of W D Snively Jr M D Medical Department Mead Johnson & Company)

Clinical Findings

1 Central nervous system stimulation (patient excited or maniacal)
2 Tissues dehydrated
3 Elevation of body temperature
4 Thirst and dry tongue

5 Renal depression (oliguria)
6 Rapid heart rate

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Comment

Often this condition is not recognized until the onset of the signs and symptoms postoperatively

III Compositional Imbalances

A Potassium Excess

Clinical Causes

1 Severe tissue damage (as in trauma or burns)
2 Severe kidney disease
3 Excessive administration of potassium

Clinical Findings

1 Gastrointestinal excitation which may cause nausea colic or diarrhea
2 Weakened myocardium

Laboratory Findings

1 Electrocardiogram
   (a) High T waves
   (b) Decrease in amplitude of R wave
   (c) Absence of P wave
   (d) Depressed S T segment
   (e) Increased duration of QRS complex
2 Usually increased plasma potassium

Treatment

1 Avoid additional potassium
2 Administer 1 ml calcium gluconate (10%) intravenously slowly with patient monitored by electrocardiograph

B Potassium Deficit

Clinical Causes

1 Chronic pyloric obstruction
2 Ulcerative colitis
3 Healing phase of burns
4 Intestinal fistula
5 Diarrhea
6 Prolonged parenteral administration of potassium free solutions
7 Repeated injections of ACTH or cortisone
8 Diabetic acidosis
9 Vomiting
10 Diuresis
11 Gastrointestinal tube drainage
12 Ileostomy

Clinical Findings

1 Moderate deficit
   (a) Weakness
   (b) Neuromuscular excitation

2 Severe deficit
   (a) Neuromuscular depression
   (b) Gastrointestinal depression (ileus)

Laboratory Findings

1 Electrocardiogram
   (a) Prolongation of Q T interval due to low, broad T wave
   (b) Inversion or lowering of T wave
   (c) Depression of S T segment
   (d) Low voltage
2 Alkalosis refractory to sodium chloride or acidosis refractory to sodium lactate
3 Decreased plasma potassium

Treatment

1 If kidney functioning potassium added to hypotonic Ringer s solution

Dosage

40 to 60 mEq per sq meter of body surface per day administered over the full 24 hour fluid supply

C Calcium Excess

Clinical Causes

1 Hyperparathyroidism
2 Excessive vitamin D administration
3 Excessive intravenous calcium administration

Clinical Findings

1 Hypotonicity of the muscles
2 Deep bony pain
3 Cavitation of the bones
4 Renal concretions

Laboratory Findings

1 Electrocardiogram (arranged in order of severity with increasingly ionized calcium)
   (a) Vagal bradycardia
   (b) Sinus arrythmia
   (c) Ventricular extrasystoles
   (d) Ventricular tachycardia
   (e) Ventricular fibrillation
2 Plasma calcium elevated
3 Urinary output of calcium increased

Treatment

1 Exclude calcium ions
2 Reduce cardiac irritability with barbiturates

D Calcium Deficit

Clinical Causes

1 Intestinal fistula
2 Pancreatic fistula

3 Generalized peritonitis
4 Surgical removal of parathyroid tissue
5 Steatorrhea
6 Blood transfusions

Clinical Findings

1 Neuromuscular excitation
2 Gastrointestinal excitation
3 Tissue excitation
4 Myocardial depression

Laboratory Findings

1 Electrocardiogram
   (a) Prolongation of Q T interval
2 Decreased plasma calcium phosphate may be elevated

Treatment

Administer slowly calcium gluconate intravenously U S P 10% with patient monitored by electrocardiograph

In addition to the clinical entities of potassium calcium and sodium excesses and deficits, there are compositional imbalances which result from combinations of deficits and excesses of sodium chloride organic acids, potassium, and carbonic acid For the normal concentration of cations and anions see Figure 5

In this group are listed metabolic alkalosis and acidosis and respiratory acidosis and alkalosis It is very important for the anesthesiologist to recognize these imbalances since they should definitely influence his management of the anesthesia

The pH of the blood is proportional to the carbonic acid and the base bicarbonate, and this constitutes a representative buffer system which can be very rapidly adjusted by the lungs and kidneys Diseases and anesthetic agents and technics interfere with both respiration and kidney function and handicap the effectiveness of the buffer systems particularly the carbonic acid base bicarbonate one

In acid base balance the carbonic acid and base bicarbonate is kept in the proportion of 1 20 or 1 35 mEq 27 mEq

E Metabolic Alkalosis (Base Bicarbonate Excess) The first important compositional imbalance is metabolic alkalosis It may be caused by the ingestion of large amounts of sodium bicarbonate, or by loss of chloride through vomiting or gastric suction When chloride is thus lost sodium is left behind to form excessive sodium bicarbonate, and thus to weight the base bicarbonate side of the ratio Metabolic alkalosis may also be due to loss of potassium through vomiting gastric suction or through the kid-

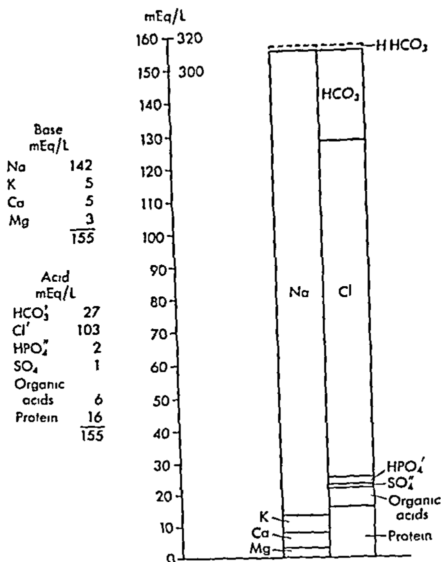


Fig 5 Acid base composition of blood plasma (Reprinted by permission of Harvard University Press from James L Gamble *Chemical Anatomy Physiology and Pathology of Extracellular Fluid* Copyright by J L Gamble 1942 Copyright by the President and Fellows of Harvard College 1947 and 1954)

neys In such a metabolic alkalosis there is an increase in the base bicarbonate The pH of the blood becomes more alkaline than normal, and the carbon dioxide combining power is usually increased

Clinical findings in uncompensated metabolic alkalosis may consist of tetany or convulsions or there may be no abnormal signs at all

Laboratory findings include an alkaline urine However, if there have been great losses of fluid or a severe loss of gastric juice through vomiting or gastric suction the urine may actually be acid in alkalosis

Compensation includes respiratory depression and an increased excretion of sodium bicarbonate by the kidneys If compensation is successful,

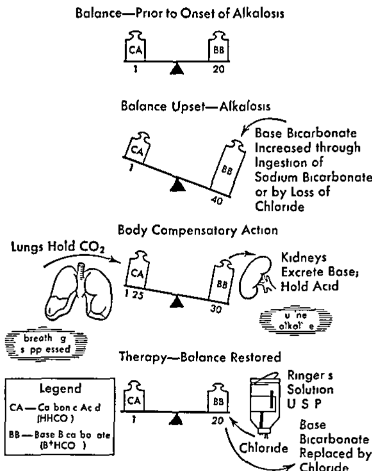


Fig 6 Compensatory mechanisms for metabolic alkalosis (Courtesy of W D Snively Jr M D Medical Department Mead Johnson & Company)

the carbonic acid base bicarbonate ratio is maintained at 1 20 (Fig 6) If compensation is not successful it is increased in favor of the base bicarbonate, with a resultant elevation of the plasma pH above the normal limit of 7 45

Therapy is directed towards supplying chloride thereby removing excess sodium or other base from the base bicarbonate side of the carbonic acid base bicarbonate ratio Normal saline is used by some and hypotonic Ringers solution is used in infants by others When metabolic alkalosis is accompanied also by potassium deficiency then potassium is added to the intravenous fluids

The pediatrician and the surgeon attempt to correct the alkalotic state with intravenous sodium chloride but frequently when the patient arrives for surgery, such as pyloromyotomy he still has metabolic alkalosis

On the preanesthetic visit to the patient, the anesthesiologist should observe carefully the frequency and depth of respiration since patients with metabolic alkalosis compensate for it by a depression of respiration It is important, however, not to depress the respiration to the point of hypoxia Therefore, it is advisable to omit or limit sedative drugs preoperatively

Endotracheal anesthesia may be used, but the anesthesiologist should either allow the patient to maintain spontaneous respirations or should simulate the preoperative respiration which allows retention of carbon dioxide It is apparent that hyperventilation in these patients will aggravate the alkalosis by engrafting a respiratory alkalosis on an already present metabolic alkalosis, thereby producing tetany

F **Metabolic Acidosis (Base Bicarbonate Deficit)** The next type of compositional imbalance coming under the general heading of acid base imbalance is metabolic acidosis The clinical causes of metabolic acidosis most frequently encountered by the anesthesiologist are severe infections as in appendicitis diarrhea diabetes mellitus, nephritis, and excessive normal saline infusions Taking appendicitis as an example excesses of ketone bodies such as β hydroxybutyric acid and acetoacetic acid are produced because of decreased intake of carbohydrate In an effort to maintain body homeostasis, the kidneys excrete these abnormal acids with sodium, thus decreasing the amount of available base bicarbonate, and in effect lightening the base bicarbonate side of the carbonic acid base bicarbonate ratio The result is a disturbance of the normal 1 to 20 ratio in favor of the carbonic acid side of the ratio The pH of the plasma becomes more acid than normal, and acidosis or acidemia exists

Certain body mechanisms attempt to compensate for the acidosis The lungs increase their action in an effort to blow off carbon dioxide, and thus to lighten the carbonic acid side of the carbonic acid base bicarbonate balance The kidneys attempt compensation by increasing acid excretion and combining these acids with the ammonia radical thus conserving sodium (Fig 7)

Although the pH of the urine is usually more acid than normal in acidosis, it may actually be alkaline when kidney infection occurs or in children under one year of age

If the compensatory mechanisms are successful then the normal ratio of carbonic acid 1 base bicarbonate 20 is maintained If these mechanisms are not successful, then the ratio is lowered The carbon dioxide combining power is decreased in metabolic acidosis

Clinical symptoms of metabolic acidosis include hyperpnea which is in

METABOLIC ACIDOSIS

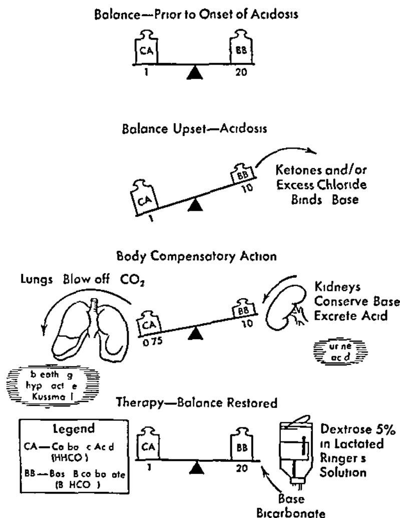


Fig 7 Compensatory mechanisms for metabolic acidosis (Courtesy of W D Snively Jr M D Medical Department Mead Johnson & Company)

reality a compensatory effort of the lungs to blow off carbon dioxide In addition, there is weakness progressing in severe cases to disorientation and stupor The plasma pH is acid in uncompensated metabolic acidosis

Treatment is directed toward supplying water to repair the fluid deficit and sodium to support the base bicarbonate side of the carbonic acid base bicarbonate ratio In most cases of metabolic acidosis there is a pronounced extracellular fluid volume deficit

In the management of metabolic acidosis carbohydrate in the form of 5 per cent dextrose in water or 1/6M sodium lactate is employed

When large amounts of saline are unwisely given the excess of chloride

in the plasma removes sodium from the base bicarbonate side of the carbonic acid base bicarbonate ratio This relative excess of chloride tends to produce acidosis The tendency is increased if sodium leaves the extracellular fluid and enters the cells as it sometimes does in potassium deficiency, thus accentuating the chloride excess

Since patients with metabolic acidosis withstand anesthesia poorly, they are usually given 5 per cent dextrose in water intravenously before anesthesia It is quite apparent that if one gives large amounts of sedative drugs to these patients before anesthesia he will handicap the compensatory action of the body by reducing the hyperpnea He will also impair the kidney function In the choice of anesthetic agents and technics he should avoid anesthetic agents such as ethyl ether which increase metabolic acidosis and dehydration In his choice of technic he should select endotracheal anesthesia so that he may reduce the dead space in the respiratory tract and have a suitable method for ventilation of the lungs to maintain the body compensatory action by keeping the alveolar carbon dioxide at a low level

G **Respiratory Acidosis (Carbonic Acid Excess)** Respiratory acidosis is caused by retention of carbon dioxide with a resultant increase of carbonic acid in the blood Emphysema and preanesthetic sedative are the most likely causes in the anesthetic cases With the increase of carbonic acid in the blood, the carbonic acid side of the carbonic acid base bicarbonate ratio is increased and the pH of the blood is more acid than normal To compensate for this there is a shift of chloride into the intracellular fluid The kidneys excrete acid and reabsorb base while the lungs attempt to compensate by hyperventilation and exhalation of increased amounts of carbon dioxide (Fig 8) But in emphysema on account of the loss of elasticity of the lungs and the decrease of air flow in them the hypercapnia cannot be reduced easily In the instances of respiratory acidosis from sedation however the carbon dioxide can be reduced more readily by hyperventilation In fact throughout the anesthesia the anesthesiologist should attempt management of respiratory acidosis by hyperventilation of the lungs

H **Respiratory Alkalosis (Carbonic Acid Deficit)** Respiratory alkalosis is caused by any condition which increases the excretion of carbon dioxide through the lungs with a resultant decrease of carbon dioxide of the blood (Fig 9) Hyperpnea from oxygen lack encephalitis or hysteria can readily do this The effect of this hyperventilation may be to produce tetany or convulsions

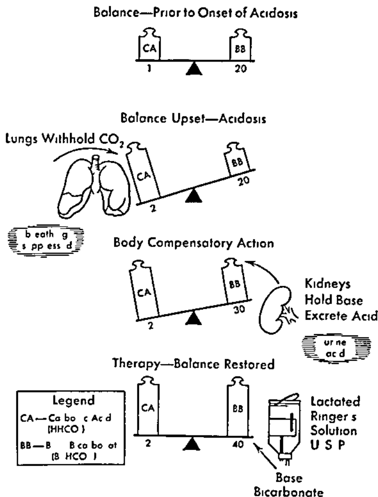


Fig 8 Compensatory mechanisms for respiratory acidosis (Courtesy of W D Snively Jr M D Medical Department Mead Johnson & Company)

The urine in these patients becomes alkaline because the kidneys excrete bases and retain acids

Sedative drugs tend to decrease the ventilation and to reduce the amount of exhaled carbon dioxide, and are therefore often advisable

Protein Metabolism

Amyloidosis This is believed to be a deposition of a complex protein within the cells of the reticuloendothelial system It is most commonly observed after long-continued suppurative conditions such as tuberculosis, syphilis, empyema, or osteomyelitis, and also in nonsuppurative diseases such as arthritis The spleen, liver, and kidneys are affected most fre-

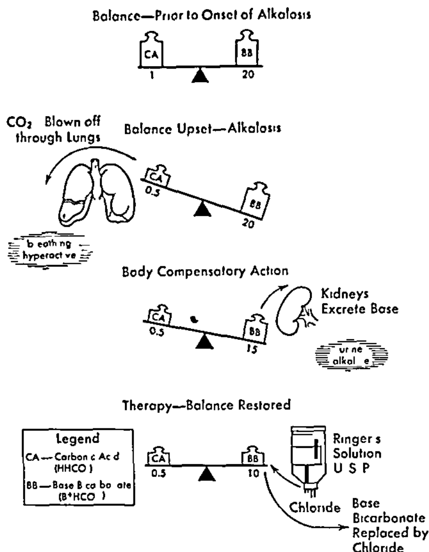


Fig 9 Compensatory mechanisms for respiratory alkalosis (Courtesy of W D Snively Jr M D Medical Department Mead Johnson & Company)

quently, although the intestine may also be involved, particularly the ileum

The increasing deposition of the amyloid causes a pressure atrophy of the parenchymal cells As hepatomegaly and splenomegaly increase ascites and edema in the lower extremities occur with albuminuria common early in the disease The patient often has some anemia and marked emaciation

Lipid Metabolism

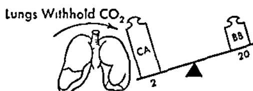
Many of the diseases characterized by abnormal lipid metabolism are still understood poorly, and the brief summaries presented will serve as a

RESPIRATORY ACIDOSIS

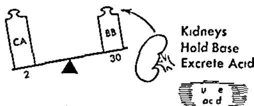
Balance—Prior to Onset of Acidosis



Balance Upset—Acidosis



Body Compensatory Action



Therapy—Balance Restored

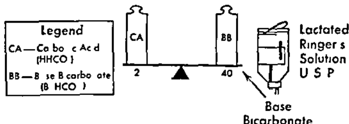


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hypertrophy with a decreased efficiency of cardiac contraction Rarely can cardiac glycogen disease be diagnosed before death, but if the cardiac shadow is enlarged by x ray without apparent cause, the possibility of this disease should be considered

Nitrogen Metabolism

Porphyria This condition is characterized by an increase in the various porphyrins in the urine and feces The urine appearing normal when first passed develops a deepening burgundy wine color on standing If the disease is congenital, the patient shows hypersensitivity to ultraviolet rays, and any exposed skin may become erythematous vesiculated and crusty, similar to the common cold sore

The acute toxic type of porphyria may occur following long ingestion of barbiturates or acetanalid or in acute infections, anemias, or liver diseases

The acquired idiopathic porphyria may be precipitated by infection It is invariably fatal Characterized by nervousness insomnia muscle weakness loss of reflexes and mental disturbances this disease may also be accompanied by abdominal pain and nausea Diagnosis may be made only on the presence of the increasing porphyrins in the urine, for patients with this type of porphyria do not have photosensitivity It has been reported that porphyria increases and prolongs the respiratory depression of barbiturates

Heat Regulation

The maintenance of body temperature depends upon the heat production and the heat loss

Heat Production The premature infant produces approximately 26 calories per sq meter of body surface per hour The normal newborn produces at the rate of 25 5 calories per sq meter of body surface per hour A child two years of age produces 50 calories per sq meter of body surface per hour as does also a child during puberty but following puberty the heat production drops progressively The adult produces about 35 calories per sq meter of body surface per hour Since the body surface of the infant and young child is considerably higher proportionally to that of the adult one can see clearly that the two-year-old child produces much more heat than the adult according to their respective weights

For every kilogram of body weight the infant has 700 sq cm of body surface whereas the adult has 200 sq cm of body surface On a weight

rough directive to the anesthesiologist in the management of the anesthesia

Gaucher's Disease Splenomegaly is the most outstanding characteristic of this disease There is a hypoplastic anemia a leukopenia and a reduction in platelets Hemorrhages occur readily from the slightest trauma Emaciation and mental deterioration may occur later in the disease, and children with Gaucher s disease also have poor resistance to infections

Niemann Pick Disease Confined almost entirely to Jewish people, this disease is of familial origin It is manifested by enlargement of the spleen and liver due to the accumulation of large reticuloendothelial cells

Lipemia This abnormal fat metabolism may be due to increase either in the neutral fat cholesterol or phospholipids It is associated with other diseases In nephrosis and hypothyroidism, the cholesterol esters are increased markedly In diabetes and pancreatitis and in some of the anemias mainly the neutral fat is increased In liver disease there may be lipemia

Progressive Lipodystrophy This condition shows a disappearance of the subcutaneous fat in the face chest and upper extremities but the fat remains in the hips and lower extremities The onset may occur as early as the second year of life but as a rule shows up later in childhood The skin has a transparent appearance and the muscles are prominent Although not usually physiologically serious the disease does cause disturbing configuration

Carbohydrate Metabolism

Ordinary forms of diabetes and hypoglycemia being familiar to most physicians, will not be discussed here

The metabolism of certain children is inadequate to handle some forms of sugar In levulosuria and galactosuria the liver cannot convert levulose and galactose to glycogen Some children with galactosuria show hepatomegaly and mental retardation Pentosuria may follow ingestion of large quantities of fruit juice or berries and is inconsequential

Glycogen Disease (von Gierke's Disease) This disease is characterized by large accumulations of glycogen in the liver heart and kidneys The basic difficulty seems to be in a failure of glycogenolysis The smooth muscle in patients with pyloric stenosis often contains an excess of glycogen If the liver is affected predominantly there is often enlargement of the abdomen There may be bouts of ketosis hypoglycemia, and recurrent vomiting Often the diagnosis can be confirmed by the presence of hypoglycemia and ketosis The disease is not necessarily fatal

In some cases the glycogen deposit is predominant in the heart causing

hypertrophy with a decreased efficiency of cardiac contraction Rarely can cardiac glycogen disease be diagnosed before death but if the cardiac shadow is enlarged by x ray without apparent cause, the possibility of this disease should be considered

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For every kilogram of body weight the infant has 700 sq cm of body surface whereas the adult has 200 sq cm of body surface On a weight

basis, the premature infant produces 2 20 calories per kg of body weight per hour The normal newborn during the immediate postnatal period has a very low heat production of 1 75 calories per kg of body weight per hour, but this production rises rapidly, and from the end of the first month into the third year it is well over 2 calories per kg of body weight per hour This is in sharp contrast to the smoldering furnace of the adult who develops only 1 calorie per kg of body weight per hour The reduced heat production during the first few days of life can be accounted for by the fact that during this period there is no shivering Furthermore activity is somewhat reduced, although the infant undergoing vigorous crying can increase its heat production by 65 to 200 per cent

Heat Loss The heat loss in the newborn is large because of its relatively large surface area and its comparatively meager subcutaneous layer of insulating fat Modifying this heat loss is the lack of perspiration in the newborn

All these features are even more exaggerated in the premature or poorly developed infant These infants regain temperature loss very slowly As well the mature infant is better prepared to adapt to its environment by an increase in its vasomotor response so that often it will show much higher rectal than skin temperature The premature infant, on the other hand shows striking parallelism between skin and rectal temperatures

Hypothermia

Cachectic infants may develop hypothermia before operation unless they are kept in an incubator or a warm room This applies also to infants who have been fed intravenously for two or three days before operation These infants often have shallow respirations later even further depressed by cooling in an air conditioned operating room

Hyperthermia

Very hot weather excessive drapes, severe infections dehydration or large dosages of scopolamine or atropine may result in an elevation of temperature Under any of these circumstances the patient has overworked respiratory and circulatory systems and exhaustion of these systems may be prevented by cooling the patient before surgery A pulse rate of 160 can be slowed to 100 a respiratory rate of 80 per minute can be reduced to 30 or 40 per minute, and a body temperature can be lowered from 42° C to 35° C If this cooling procedure is enforced the patient will have a better opportunity of surviving the operative period

In the premature and the newborn, heat regulation is particularly important since the advent of air conditioned operating rooms In such a room an infant in a few hours may lose several degrees of temperature In spite of the advantages of hypothermia in some conditions, it is believed important to maintain body temperature in the premature, the neonate, and the cachectic infant Consequently, the anesthesiologist raises the operating room temperature for such a patient or places him on a plastic mattress through which circulates warm water, and then regulates the temperature of the patient which is recorded continuously by a rectal thermometer The normal infant beyond the neonatal period and the child seem better adapted to resist alterations in body temperature

VITAMINS

Vitamin Deficiency

A maternal history recording the intake of vitamins during pregnancy is invaluable, since the newborn infant may suffer from avitaminosis This is also true of infants who have been deprived of adequate vitamin intake as a result of artificial feeding

Vitamin A Vitamin A may be deficient in the diet in hepatic or pancreatic disease, or intestinal disorders when there is lack of absorption of vitamin A Children with this condition fail to gain weight, have nightmares and may have some dryness and scaliness of their skin

Vitamin B_1 (Thiamine Chloride) (Beriberi) This occurs in infants who are on artificial feedings or whose food is overcooked Patients are irritable lose their appetite vomit, have constipation and edema The heart may be affected, resulting in tachycardia, cyanosis, shortness of breath and cardiac enlargement If nervous system signs predominate, there will be drowsiness, loss of tendon reflexes, and peripheral neuritis

Vitamin B_2 (Riboflavin) With this deficiency the patient has loss of weight smoothness and redness of the tongue, redness of the cornea photophobia, and excessive lacrimation

Vitamin B_6 (Pyridoxine) The most outstanding sign in this condition is convulsions which may occur early in infancy but are more marked during the second month of life

Niacin (Pellagra) Children with niacin deficiency have weakness, loss of appetite, and erythema on the exposed parts of the body If the disease is severe, there may be gastrointestinal symptoms, swelling and redness of the tongue

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pain relieving drugs before an operation, he should be given the same for preanesthetic medication

DISEASES OF THE RETICULOENDOTHELIAL SYSTEM

This includes Hand Schuller Christian syndrome, Letterer-Siwe disease and eosinophilic granuloma These three diseases are characterized by granulomatous changes in the reticuloendothelial system

Hand-Schuller Christian Syndrome

This serious chronic disease, occurring usually before the age of six years classically shows defects in the membranous bones such as the skull, exophthalmos and diabetes insipidus Diffuse infiltration of the lungs may occur

Letterer-Siwe Disease

This is a rapidly fatal disease of infancy or early childhood In addition to the defects in the bony skull there are splenomegaly hepatomegaly anemia and skin eruptions

Eosinophilic Granuloma

Occurring in older children, this disease is often characterized only by bony defects in the skull bones It is the mildest of the three mentioned diseases of the reticuloendothelial system

COLLAGEN DISEASES

Rheumatic Fever

Rheumatic fever is more likely to cause permanent damage to the myocardium and valves of the heart than any other acute infection It is subject to recrudescence When the fever is endemic it is more likely to recur in the winter months Therefore, any elective surgery should be undertaken during the summer months

Although antibiotics and salicylates have done much to modify rheumatic fever and its effect on the myocardium there are times when the anesthesiologist is required to anesthetize children who are cardiac cripples from the disease Any drugs which would interfere with the contractility of the myocardium are dangerous Large rapid intravenous dosages of barbiturates spinal anesthesia, or deep ether anesthesia should be avoided

Vitamin C (Ascorbic Acid) (Scurvy) Seen most frequently between the age of seven months and two years, vitamin C deficiency results in irritable patients with tenderness of the extremities, probably due to subperiosteal hemorrhages The gums are purplish and swollen, and there may be depression of the sternum The bones may show a typical ground glass appearance in the x-rays There may be blood cells in the urine

Vitamin D (Rickets) This is usually due to inadequate intake of vitamin D or lack of the ultraviolet rays of sunshine It generally does not occur until three months of age, at which time it is characterized by craniotabes delayed closure of the fontanelles, delayed dentition pigeon breast depression along the insertion of the diaphragm deformity of the pelvis poor muscle tone with protrusion of the abdomen weakness and constipation The bones fracture easily Serum calcium may be normal unless tetany occurs Serum phosphorus is decreased and alkaline phosphatase is increased

Vitamin K A newborn infant may have massive pulmonary or abdominal hemorrhages, the frequency of which is decreased if the mother has had vitamin K before the delivery of the infant However if the mother has not had vitamin K and time is available before operation on the infant, he should have 4 to 10 mg intravenously to reduce the hemorrhagic diathesis Such administration of vitamin K is thought to decrease the prothrombin time to near the normal levels

Hypervitaminosis

Occasionally the anesthesiologist encounters a patient who has been too vigorously treated with vitamins particularly vitamin A These patients have carotenemia resulting in a light yellowish discoloration of the skin but there is no discoloration of the conjunctiva Thus carotenemia is usually easily differentiated from jaundice

However the excess vitamin invades the liver and spleen and the patient may suffer anemia and leukopenia

NEW GROWTHS

Statistically there is an increase in malignancy among infants and children in recent years It is usually of a very fulminating type producing extreme emaciation malnutrition and anemia Patients with malignancy are very ill with impaired myocardial function and each patient must be considered individually If the child has been receiving large dosages of

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because they may cause a precipitous drop in blood pressure and acute cardiac failure

Rheumatoid Arthritis

Rheumatoid arthritis is a slow, progressive disease affecting the lungs pericardium lymphatic tissues, skin, and later the joints The onset which may be acute or gradual does not occur ordinarily until after the second year of life It is characterized by fever joint pains (especially of the hands and feet) weight loss, clammy skin muscle aches, and tremors The joints are swollen slightly tender, with limited motion and they become characteristically spindle-shaped, covered by shiny, smooth skin *Tachycardia, pericarditis large lymph nodes, large spleen, renal disease,* and subcutaneous nodes (especially along the ulna and spine) may occur

Laboratory findings show leucocytosis increased sedimentation rate and a reversed albumin globulin ratio There may be a hypoplastic anemia and an elevation of the serum polysaccharides X-rays of the bones show slight widening of the joint spaces and, later, osteoporosis of the bones

In order to prevent the crippling kyphosis which may occur with rheumatoid arthritis a patient is often given a course of cortisone therapy, necessitating the anesthesiologist s attention to continued steroid replacement

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syndrome, and, if metabolic alkalosis is present, sodium chloride should be administered before surgery

Ichthyosis

This condition varies from slight dryness of the skin to very marked scaling Even a newborn infant may manifest the disease by a marked dryness of the skin A patient with ichthyosis may develop a rise in temperature with small dosages of atropine For this reason the body temperature should be monitored and controlled as in dysautonomia

Ehlers Danlos Syndrome

Particular attention to careful handling is the prime requisite in the management of these patients for their skin and joints are especially susceptible to injury The syndrome itself is manifested by hyperelasticity and friability of the skin with hyperextensibility of the joints

Sclerema Neonatorum

This usually fatal disease, characterized by hardening of the tissues, generally commences around the buttocks and thighs and then spreads cephalad, gradually involving the upper part of the body The tissue neither pits nor swells but merely becomes a firm inelastic mass, thus differentiating it from the less serious disease scleroderma

According to Parmelee sclerema is the result of solidification of the subcutaneous fats due to lowered body temperature Characteristically fetal fat is low in oleic acid and high in palmitic acid content and since fat of this composition has a high melting point it can readily solidify at low temperatures

One preoperative and five postoperative fatal cases of sclerema in the newborn were seen by the authors in a two month period Since this experience a continuous recording rectal or esophageal thermometer has been used to monitor the temperature of infants under six weeks of age, and in addition careful attention is directed toward maintenance of the newborn s body temperature by means of a heated operating room and a heated pad on the operating table Since the implementation of this procedure the absence of sclerema neonatorum appears to confirm Parmelee s hypothesis

CHAPTER 2

EVALUATION OF THE INTEGUMENTARY SYSTEM

Pediatric dermatologists attribute many of the diseases of the integumentary system to emotional disturbances and some of the diseases described below mav be of that origin However, several other integumentary diseases are either congenital or traumatic in origin Because of widespread systemic effect these diseases may influence anesthetic choice and management

PRENATAL INFLUENCES

Riley-Day Syndrome (Dysautonomia)

This syndrome which occurs mainly in Jewish children, has several characteristics which influence the anesthetic management The tendency to have an exaggerated reaction to mild anxiety is controlled by increasing the sedative in the premedication and by supplying sedatives postoperatively In these patients the absence of sweating causes pyrexia therefore body temperature should be monitored and controlled by body cooling Absence of lacrimation may result in corneal ulceration but this is forestalled by the instillation of 5 per cent boric acid ointment and taping the eyelids closed Indeed in lengthy procedures the eyelids may even be sutured shut Extreme fluctuations of blood pressure may occur varying from the awake, alarmed hypertensive preinduction state to a sudden profoundly hvpotensive state following induction Therefore light planes of anesthesia should be maintained Protracted vomiting may be part of the

Ruptured alveoli in the deeper recesses of the lung may cause an escape of pulmonary gases which travel up the blood vessels into the mediastinum and later into the subcutaneous tissues of the neck. Subcutaneous emphysema in the neck following a tracheostomy generally indicates that the skin is closed too tightly around the tracheostomy tube.

The presence of subcutaneous emphysema demands an investigation into the causes, since it invariably indicates an impaired respiratory system. It would also suggest that forceful artificial ventilation of the lungs might increase the respiratory embarrassment.

Cicatrix

Extensive cicatrix of the body often indicates a prolonged period of previous treatment, resulting in a mounting phobia of further treatment. Consequently, profound sedation and an understanding approach to the patient are essential.

Cicatrix of the skin of the neck or mouth becomes a problem only when it tends to immobilize the lower jaw, drawing it closer to the thorax. The advisability of a preoperative tracheostomy should be discussed with the surgeon, since, if obstruction to respiration should occur during anesthesia, it might be very difficult to establish the patency of the airway either by intubation or an emergency tracheostomy.

Contusions

In spite of laboratory tests showing normal bleeding and clotting times, the possibility of a bleeding tendency in a male patient who is covered with numerous unexplained bruises should not be overlooked. Nasal intubation in such a patient may initiate a stubborn epistaxis.

We can recall a tonsillectomy being performed in such a patient in which more than three hours were spent trying to stem the flow of blood from the fauces. Eventually transfusions had to be administered and the carotid artery tied. This incident happened even though the bleeding and clotting times were recorded as normal.

CYANOSIS

Acrocyanosis

Acrocyanosis in the hands and in the feet or in the feet alone occurs in many infants during the first few hours of life. It may represent a slight degree of shock which the infant has suffered in his passage through the birth canal, or it may be due to inadequate expansion of the lungs. In the

Congenital Ectodermal Dysplasia

In this familial disease the patient demonstrates edentulism, sparseness of the hair atrophy of the nails, glossiness of the skin, with frequent absence of sweat and sebaceous glands

There are two types, hidrotic and anhidrotic A patient with the hidrotic type can control his very labile temperature bv profuse perspiration, while a patient with the anhidrotic type is subject to greater variations in temperature since he lacks the ability to perspire

Patients with congenital ectodermal dysplasia may show an extreme rise in temperature from a heated environment or from any of the belladonna drugs like atropine or scopolamine These drugs must be used with caution, and a continuous recording of the body temperature must be kept preoperatively, operatively, and postoperatively The anesthesiologist must be prepared to cool the patient if the temperature rises

INFECTIONS

Impetigo

Since impetigo is very contagious in the newborn, strict isolation technic must be employed to prevent the contamination of other infants

Furunculosis

Multiple furuncles of the skin occur rarely in children under five years of age, although a condition closely akin to it is seen in the marasmic infant A marasmic infant often shows multiple abscesses in the skin with very little inflammation Children who have had pyemic infection for a long period of time are increased anesthetic risks, probably because of a reduced myocardial reserve

TRAUMA

Subcutaneous Emphysema

The presence of subcutaneous emphysema may be due to gas gangrene but usually indicates a rupture of the alveoli bronchioles or any other part of the respiratory tract The escaping pulmonary gases may cause a pneumothorax, and if it is a tension pneumothorax not only will the mediastinum be pushed to the opposite side but also the gas itself can escape through a perforation in the chest wall passing into the subcutaneous tissues

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Cicatrix of the skin of the neck or mouth becomes a problem only when it tends to immobilize the lower jaw, drawing it closer to the thorax The advisability of a preoperative tracheostomy should be discussed with the surgeon since, if obstruction to respiration should occur during anesthesia, it might be very difficult to establish the patency of the airway either by intubation or an emergency tracheostomy

Contusions

In spite of laboratory tests showing normal bleeding and clotting times, the possibility of a bleeding tendency in a male patient who is covered with numerous unexplained bruises should not be overlooked Nasal intubation in such a patient may initiate a stubborn epistaxis

We can recall a tonsillectomy being performed in such a patient in which more than three hours were spent trying to stem the flow of blood from the fauces Eventually transfusions had to be administered and the carotid artery tied This incident happened even though the bleeding and clotting times were recorded as normal

CYANOSIS

Acrocyanosis

Acrocyanosis in the hands and in the feet or in the feet alone occurs in many infants during the first few hours of life It may represent a slight degree of shock which the infant has suffered in his passage through the birth canal, or it may be due to inadequate expansion of the lungs In the

latter, inhalation of high concentrations of oxygen cures the cyanosis In persistent cases, the possibility of congenital heart disease must be entertained

Generalized Cyanosis

Generalized cyanosis is indicative of either respiratory or cardiovascular disease of extreme severity

No cyanotic patient should be depressed with preanesthetic sedatives nor should he be given any anesthetic agent which does not allow a high concentration of oxygen to be administered conjointly

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CHAPTER 3

EVALUATION OF THE MUSCULOSKELETAL SYSTEM

DISEASES OF THE BONES

PRENATAL INFLUENCES

Osteogenesis Imperfectum (Fragilitas Ossium)

The rarefied bones of patients with osteogenesis imperfectum are susceptible to innumerable fractures, therefore movement of such a patient should be done with the assistance of the orthopedic surgeon in order to avoid further fractures of the patient's fragile bones Since deafness often accompanies this disease, it may be difficult for the anesthesiologist to establish rapport with the patient

However, due to the marked flaccidity of the musculature, frequently only analgesia is necessary, and light planes of anesthesia are sufficient in this condition

Osteopetrosis (Marble Bone)

The opposite of osteogenesis imperfectum this familial disease exhibits an increased density of the bones However they are brittle and can fracture very easily and movement of these patients should be carried out with the same degree of care as outlined for osteogenesis imperfectum Visual and auditory defects may also be noted in this condition

Leontiasis Ossium

This particularly well named hereditary disease is characterized by an overgrowth of the cranium, especially notable in the frontal region, giving the child a leonine appearance This is further heightened by flattening of the nasal ridge, hollowing of the cheeks, and an increased intraocular space (hypertelorism) The vision may be threatened by the growth of bone around the optic nerve To save the vision it may be necessary to free the optic nerve often a time consuming procedure because of the thickness of the bone Intubation is often difficult because of limitation of mandibular excursion

Pectus Excavatum (Funnel Chest)

The cause of the depressed sternum is unknown, but some hereditary factor is believed to exist Generally present at birth or very soon thereafter, the disease sometimes occurs in more than one member of a family

In the more severe afflictions, the attached cartilages are depressed As the ribs grow the sternal depression increases, and the thoracic cage fails to increase in rigidity in the normal manner Consequently during inspiration the sternum retracts as the abdomen protrudes, and with this paradoxical breathing the stomach may readily become distended with air

Not all patients with pectus excavatum require surgery for the condition, but this decision can be made by the time the patient is three or four years of age Surgical correction is a twofold therapy elimination of cardiorespiratory distress, and correction of the deformity for psychological reasons

In the extensive operation for pectus excavatum, massive blood loss may occur, therefore blood must be readily available

INFECTIONS

Osteomyelitis

Acute osteomyelitis is no longer a surgical disease and even the chronic form is rare however chronic osteomyelitis or tuberculosis of the bone may cause amyloid disease and reduced cardiac reserve Such a patient often has depression of respiration with ordinary dosages of premedication Hypotension and even cardiac arrest can occur with a slight increase in the amount of anesthetic agent

TRAUMA—FRACTURES

Fractures of the Large Bones

The severe blood loss occasioned by fractures of the large bones may at times result in a shock state which is correctly treated with blood transfusion If open reduction is performed further blood loss will undoubtedly occur, adequate blood replacement is essential and must be anticipated

DISEASES DUE TO METABOLISM, GROWTH, OR NUTRITION

Renal Osteodystrophy

In this disease there is osteoporosis, decrease in blood calcium and increase in urinary calcium The osteoporosis necessitates careful movement of the patient The decrease in blood calcium may give a relative hyperkalemia with depressant effect on the myocardium The increased urinary calcium may produce renal pelvic calculi and infection The extent of these lesions determines the anesthetic risk involved

Osteitis Fibrosa Cystica

Due to hyperparathyroidism areas of bony structure become rarefied The affected bones are fractured easily, and gentle movement of the patient is essential We have never encountered any unusual anesthetic complications due to elevated blood calcium

DEVELOPMENTAL

Micrognathia

See Chapter 4 Pierre-Robin syndrome (p 80)

NEW GROWTHS

Malignant Bone Tumors

The common varieties of malignant bone tumors in children are chondrosarcoma, fibrosarcoma and Ewing s sarcoma These tumors grow so rapidly that their presence is detected early before the health of the patient has deteriorated

Usually an amputation of the involved limb is attempted Prior to amputation the patient s blood should be typed and cross matched for pos-

sible blood transfusions, while heavy premedication relieves the patient of postoperative discomfort and pain

DISEASES OF THE JOINTS

INFECTIONS

Mandibular Joint

Infection of the mandibular joint usually restricts the movement of the mandible increasing the difficulty of oral intubation therefore, blind nasal endotracheal intubation may be preferable However a severe degree of fixed occlusion necessitates an elective tracheostomy before major surgery

DISEASES OF THE MUSCLES

PRENATAL INFLUENCES

Myotonia Congenita (Thomsen's Disease)

This is characterized by intermittent bouts of increased tone in groups of muscles in the body Since the disease may be due to excess acetylcholine, it is intensified by potassium or anticholinesterase drugs such as neostigmine (Prostigmin)

These patients should be given one and a half times the standard dosages of atropine or scopolamine for preanesthetic medication thus reducing the respiratory tract secretions and protecting the heart from cholinergic effects

Muscular Dystrophies

These patients often show easy fatigue because of initial muscular hypertrophy and subsequent muscle fiber replacement by fibrous connective tissue The gravest hazard is pneumonia since such children may lack an effective cough The lightest of premedication is essential while muscle relaxants and deep anesthesia are avoided

DISEASES DUE TO DISTURBANCE OF INNERVATION OF MUSCLES

Myasthenia Gravis

Neonatal This disease is often transient The patient demonstrates muscular weakness weak Moro reflexes a feeble cry and poor sucking and

swallowing reflexes accompanied by masklike facies Immediate relief of the symptoms by injecting intramuscularly 0 1 ml (1 0 mg) of edrophonium chloride (Tensilon) confirms the diagnosis of neonatal myasthenia gravis

Neonatal myasthenia gravis may occur in infants of mothers who have myasthenia gravis

Juvenile Often recognized by a bilateral ptosis and masklike facies, further manifestation of this disease is by weakness of the muscles of the neck, trunk, and limbs The pupils are usually constricted These patients have difficulty in learning to walk, while older children tire more readily The diagnosis is made on the marked improvement following the injection of 0 2 ml (2 0 mg) of edrophonium chloride Neostigmine is a valuable therapeutic drug Curare or similar drugs have a long lasting effect on patients with myasthenia gravis or on patients with a past history of the disease, and their use is avoided Omission of this precaution may cause a very prolonged apnea

DISEASES DUE TO DISORDERS OF METABOLISM

Ossifying Myositis

Progressive ossifying myositis may be seen in the newborn, but usually occurs later in the first decade of life The muscles of the neck and back are often predominantly affected However, contraction of the muscles of respiration may also be hindered In such instances, reduced dosages of sedative drugs in the premedication permit the fullest activity of the respiratory muscles

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CHAPTER 4

EVALUATION OF THE RESPIRATORY SYSTEM

Since the welfare of the patient is dependent for the main part upon the efficient conveyance of oxygen and carbon dioxide by the respiratory and cardiovascular systems evaluation and management of these systems must of necessity occupy the principal attention of the anesthesiologist However during development in the infant many morphologic and physiologic changes became manifest all of which affect the choice and management of anesthetic technics In this chapter the respiratory considerations will be discussed

ANATOMY

Thorax

In the newborn the thoracic cage is semirigid and easily retracted by the descent of the diaphragm The ribs horizontally orientated at birth begin their oblique orientation toward the end of the first year and complete this orientation by the end of the fourth year (Fig 10) The perimeter of the thoracic cage increases 50 per cent during the first year but only 10 per cent during the second year since the thoracic cage enlarges volumetrically both by descent of the diaphragm and change in angulation of the ribs At birth the level of the diaphragm is in the region of T8 9 while at maturity it is at T9 10 with the left leaf of the diaphragm slightly lower than the right

Although at birth the thoracic cage appears to be occupied by the rela

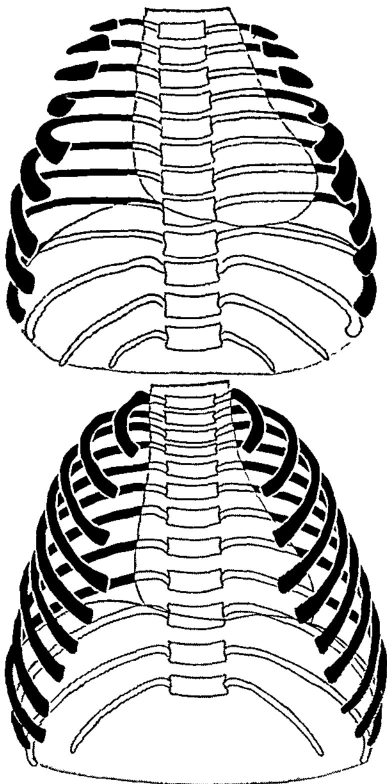


Fig 10 *(Above)* Horizontal position of ribs at birth *(Below)* Oblique position of ribs at end of fourth year

tively large heart and great vessels, in later infancy developmental changes enlarge the thoracic cage and rapidly provide more space for the expanding lungs

Mouth and Oronasopharynx

The newborn and infant are accustomed to nasal breathing Adenoids rarely obstruct respiration until the child is beyond infancy However, the large tongue of the infant and his edentulous state result in close apposition of the tongue and palate with consequent obstruction to the oral airway

Larynx

The larynx is positioned more cephalad in the newborn than in the adult with a fusion of the thyroid and hyoid cartilages (Fig 11) The small epi-

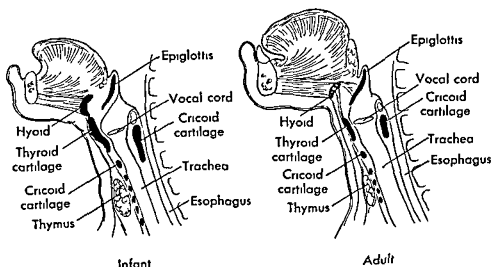


Fig 11 *(Left)* Cephalad position of larynx in newborn with fusion of thyroid and hyoid cartilages *(Right)* More caudad position of larynx in adult with separation of thyroid cartilage and hyoid bone (Eckenhoff J E Some Anatomic Considerations of the Infant Larynx Influencing Endotracheal Anesthesia *Anesthesiology* 12 403 1951)

glottis usually corresponds in relative size to that of the lower jaw Since it is V-shaped, stiff and extends more posteriorly over the entrance to the glottis, intubation in the newborn is generally more difficult than in the older child or adult The posterior cartilaginous portion of the vocal cords is about the same length as the anterior ligamentous portion (Fig 12) As the infant develops the increase in the length of the vocal cords is brought about by an increase in the ligamentous portion

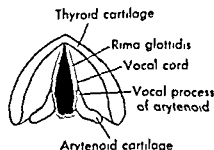


Fig 12 Larynx of young child transverse section Anterior ligamentous portion lengthens with age (Eckenhoff J E Some Anatomic Considerations of the Infant Larynx Influencing Endotracheal Anesthesia" *Anesthesiology,* 12 404 1951)

Trachea

The trachea extends from the vocal cords to the carina At birth, it lies to the right of the midline but later on moves more medially It is embedded in loose connective tissue, and is shifted easily to either side by changes in the intrapleural pressure Generally speaking the bifurcation of the trachea in the first year lies between the third and fourth thoracic vertebrae, from two to six years, between the fourth and sixth thoracic vertebrae, and from seven to twelve years, between the fifth and sixth thoracic vertebrae

The trachea grows from 4 cm at birth to only 6 3 cm at twelve years of age while the sagittal diameter at birth is 5 mm and reaches 16 5 mm in the adult (Fig 13) The diameter of the trachea in the newborn is there-

Age	*Length*	*Diameter* (Engel) Sagittal	Coronal
Months	cm	mm	mm
0–1	4 0	5 0	6 0
1–3	3 8	6 5	6 8
3–6	4 2	7 6	7 2
6–12	4 3	7 0	7 8
Years			
1–2	4 5	9 4	8 8
2–3	5 0	10 8	9 4
3–4	5 3	9 1	11 2
4–6	5 4	—	—
6–8	5 7	10 4	11 0
8–10	6 3	—	—
10–12	6 3	9 3	12 4
12–14	6 4	—	—
14–16	7 2	10 7	13 5
Adult	9–15	16 5	14 4

Fig 13 Dimensions of trachea from birth to adult life (Engel S *The Child's Lung* Edward Arnold (Publishers) Ltd , London 1947)

fore relatively large compared with that of the adult and signifies a large anatomical dead space The trachea and bronchi increase rapidly in caliber during the first few months of life but the rate of increase is not quite so rapid from then on to the end of the fourth year From the fourth year to the beginning of puberty there is very slight increase in diameter, but with the onset of puberty and continuing to adult life there is once again a rapid increase in the diameter of both the trachea and bronchi

In the newborn the shape of the trachea is maintained by the cartilaginous rings which are immature and soft in structure While there are numerous glands in the tracheal wall they are not developed completely, probably accounting in part for the paucity of secretion in the trachea during the first week of life For this reason, anticholinergic drugs are necessary only if the anesthesiologist desires to obtund vagal reflexes

Bronchi

The bronchi angle more sharply from the trachea in the infant under one year than in the adult

At birth the caliber of the right bronchus is slightly larger than that of the left and this ratio is maintained until adult life (Fig 14) Up to the age of four years the combined area of the cross sections of the two main bronchi gradually increases over that of the trachea and in adult life is 40 per cent greater

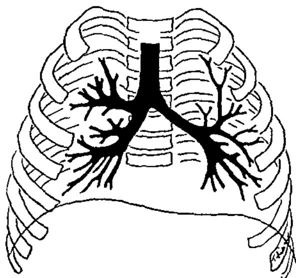


Fig. 14 Caliber of right bronchus is larger than the left in infants and children

Lungs

The lungs may be described in terms of three zones first, the hilum which contains only bronchi blood vessels glands and nerves, all united by loose connective tissue, second the central area next to the hilum wherein lie the bronchi, arteries, and veins with lung tissue in the interspace, beyond this, and toward the periphery, is a third zone composed of lung tissue and bronchioles the expansile portion of the lung

At birth, the bronchioles are very delicate, but the muscle layer commences to grow thicker and elastic fibers increase in number and size during the first year of life Consequently for the first few months of life the infant s lung has a paucity of firm supporting structure and a minimum of elasticity, both conditions favoring either pulmonary hyperdistention or atelectasis with minimal initiating cause

The main functional part of the lung consists of alveolar ducts, the central spaces giving rise to the cup-shaped alveoli In the walls of these alveoli are fine elastic fibers a few connective tissue cells, and pulmonary capillaries Alveolar ducts are extremely small, and since they dilate gradually during the first few days of life some clinicians believe that if operations on the newborn are delayed for a few days there are fewer respiratory complications during and following anesthesia The subsequent increase in the size of the lungs probably results chiefly from an increase in the size of the alveolar ducts and the alveoli Due to the marked immaturity of alveolation and abundance of mesenchymal tissue in the infant the specific weight of the lung tissue at birth is about four times that of the adult and even at the age of four years it is still twice that of the adult Such a microscopic structure suggests that the total respiratory surface is relatively smaller in the newborn than in the older child

PULMONARY PHYSIOLOGY

Mechanics of Respiration in the Newborn

From an anatomical comparison of the respiratory systems of the infant and the adult physiological differences are expected in the two age groups A comparison of the results of some pulmonary function tests that have been made are listed in Figure 15

The newborn infant breathes through his nose and does not adjust readily to mouth breathing The dominant muscle of respiration is the diaphragm and its degree of excursion is limited by the large liver spleen

and abdominal contents At birth the ribs are elevated, so that little increase in the size of the thoracic cage can be obtained through the contraction of the intercostal muscles In fact when there is a demand for increased pulmonary ventilation, there may be marked indrawing of the semirigid anterior wall of the thorax as the diaphragm contracts and descends

	2 5 kg Infant	*70 kg Adult*
FRC	70 ml	2400 ml
TV	15 ml	500 ml
Rate	34/min	12/min
MV	498 ml	6000 ml
VC	140 ml	4800 ml
AV	355 ml/min	4200 ml/min
FDS	5 ml	150 ml
pCO_2	32 mm Hg	40 mm Hg
Compliance	5 ml/cm H_2O	100 ml/cm H_2O
O_2 consumption	12–20 ml/min	250 ml/min
CO_2 elimination	14 ml/min	200 ml/min

Fig 15 Comparison of normal pulmonary function values in infant and adult (*Infant pulmonary function values adapted from Cook C D Lucey J F Drobaugh J E Segal S Sutherland J M and Smith C A* Apnea and Respiratory Distress in the Newborn Infant Physiologic Background Resuscitation and Supportive Technics *New England J Med* 254 565 1956 Adult pulmonary function values adapted from Comroe J H Jr Forster R E Dubois A B Briscoe W A and Carlsen E *The Lung Clinical Physiology and Pulmonary Function Tests* The Year Book Publishers Inc Chicago 1955)

The differences in normal respiratory measurements between the newborn and the adult are shown in Figures 16 and 17

Functional Residual Capacity This is the volume of gases remaining in the lungs at resting expiratory level In the normal patient this represents the reserve of air in the lungs The normal infant has a small reserve, which coupled with high oxygen consumption accounts for the hypoxia that can occur in two or three minutes It is suspected that the residual capacity may be even lower the first few days of life before the infant has had time to expand his alveoli

Tidal Volume This is the amount of air inspired or expired during each respiratory cycle (Fig 18) A nomogram (Fig 19) has been devised which enables the determination of the optimum tidal volume when the frequency of respiration body weight, and sex of the patient are known The nomogram has only a theoretical value in pediatric anesthesia because

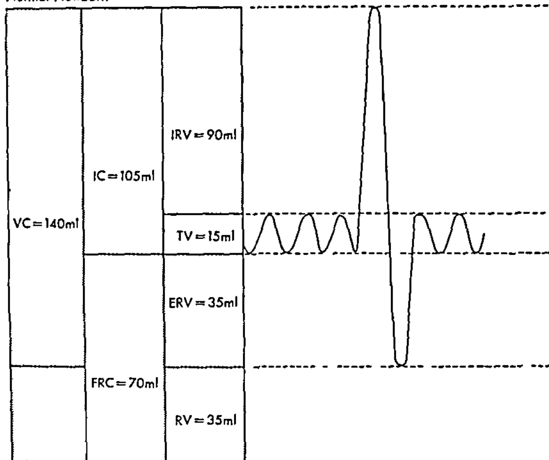


Fig 16 Diagram of pulmonary volumes in the normal newborn (Adapted from Cook C D Lucey J F Drobaugh J E Segal S Sutherland J M and Smith C A Apnea and Respiratory Distress in the Newborn Infant Physiologic Background Resuscitation and Supportive Technics *New England J Med* 254 565 1956)

the cuffed endotracheal tube which ordinarily assures a completely closed system seldom is used except in older children Consequently, there is considerable escape of gases either around the mask or around the endotracheal tube, making it impossible to use the tidal volumes of the nomogram

Pneumotachographic tracings indicate that anesthetic agents and technics on the whole tend to depress the optimum tidal and minute volume of the infant and child (Fig 20) Maximal tidal volumes in early infancy are shown in Figure 21

Frequency of Respiration The newborn infant has a comparatively small thoracic cavity which is occupied by a relatively large heart and closely packed lung tissue composed of small and only slightly expanded

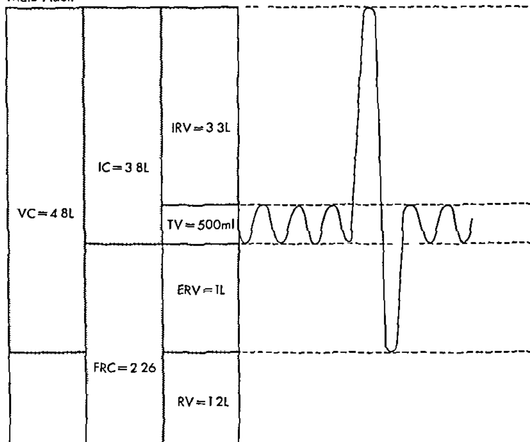


Fig 17 Diagram of pulmonary volumes in normal male adult (Comroe J H Jr Forster R E Dubois A B Briscoe W A and Carlsen E *The Lung Clinical Physiology and Pulmonary Function Tests* The Year Book Publishers Inc Chicago 1955)

alveolar ducts For this reason the infant is dependent more on increased frequency of respiration than on increased tidal volume to overcome hypoxia or hypercarbia (Fig 22)

As the infant grows older the thoracic cage enlarges and alveolar ducts expand allowing for greater variations in tidal volume Consequently if there is a demand for increased alveolar ventilation changes in tidal volume often take precedence over changes in frequency of respiration

Minute Volume Minute volume is the product of tidal volume and the frequency of respiration It is three or four times larger in the newborn than in the adult on a comparative weight basis This increased minute volume is achieved by the greater frequency of respiration of the newborn

1 month	23 cc
3 months	41
6 months	51
12 months	78
2 years	136
4 years	140
5 years	215
9 years	395

Fig 18 Tidal volume from one month to nine years of age

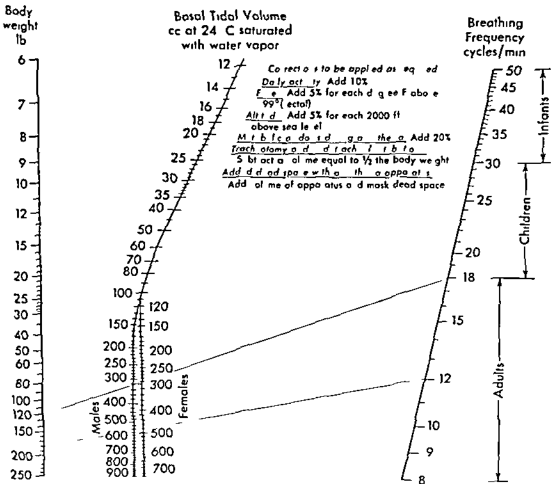


Fig 19 Nomogram for predicting the optimum tidal volume from the breathing frequency body weight and sex of the patient (Radford E P Jr Ferris B G Jr and Kriete B C Clinical Use of a Nomogram to Estimate Proper Ventilation during Artificial Respiration *New England J Med* 251 878 1954)

Compliance This is the ease of expansion of the lung as measured from the volume response of the lung per unit of pressure applied and is ex-

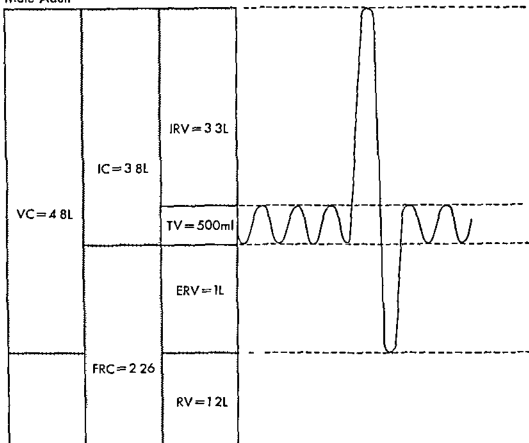


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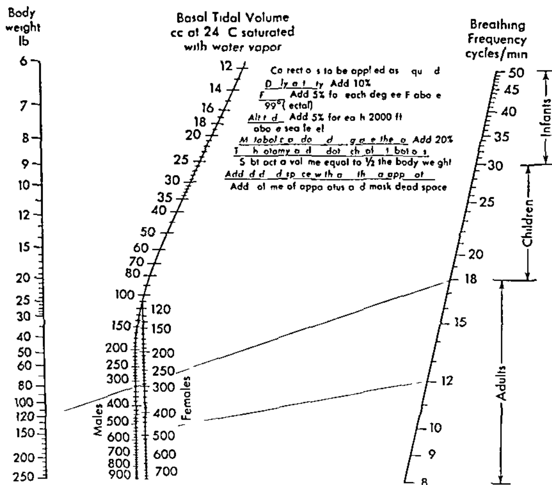


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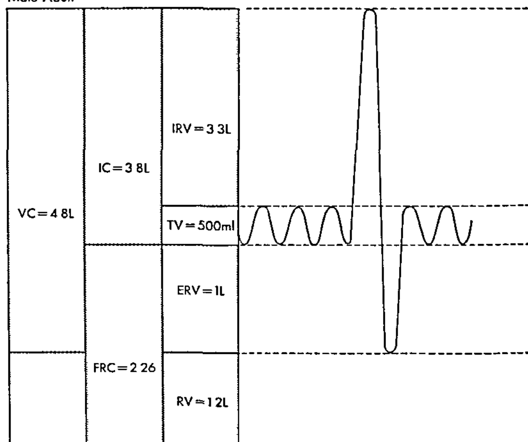


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Minute Volume Minute volume is the product of tidal volume and the frequency of respiration It is three or four times larger in the newborn than in the adult on a comparative weight basis This increased minute volume is achieved by the greater frequency of respiration of the newborn

Age in Days	*Rate per Minute*	*Tidal Air per Breath* ml	*Respiratory Volume per Minute* ml
	Range	Range	Range
1 day of birth	27–62	10–27	225–1187
2	27–82	12–25	436–1704
3	23–66	12–30	465–1103
5	25–70	15–26	550–1452
7	28–59	14–23	490–1222
9	32–80	13–27	681–1663
11	32–72	25–25	806–1774
Adult (av)	18	450 0	7100

Fig 22 Illustration showing wide range in frequency tidal volume and minute volume in the infant (Deming J and Hanner J P Respiration in Infancy *Am J Dis Child* 51 823 1936)

Day of Life	*Benedict Talbot*
First few hours	0 90
1	0 80
2	0 74
3	0 73
4	0 75
5	0 79
6	0 82
7	0 81
8	0 80

Fig 23 Respiratory exchange ratio (respiratory quotient) in newborn (Benedict F G and Talbot F B *The Physiology of the New Born Infant Character and Amount of the Katabolism* Publication No 233 Carnegie Institution of Washington Washington D C 1915)

	O_2 per Kg per Minute
Human fetus before labor	1 25 ml
Human infant before breathing	1 50 ml
Human infant during first week	6 4–7 9 ml
Premature infant during first day	6 3–6 4 ml
Human adult	3 9 ml

Fig 24 Oxygen consumption in infants and adults per kg of body weight (Smith C A *The Physiology of the Newborn Infant* 2nd ed Charles C Thomas Publisher Springfield Ill 1951)

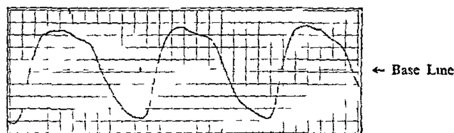


Fig 20 Pneumotachogram of a nine year-old boy weight 27 2 kg (60 lb) with a Luft orifice attached to a mask cyclopropane anesthesia (Inhalation *above* the base line Exhalation *below* the base line)

	From Pneumotachogram	*Optimum (Radford nomogram)*
Rate of respiration	30	30
Tidal volume	123 ml	145 + 150 (dead space = 295 ml of mask)
Minute volume	3690	8850
Maximum inspiratory flow rate	9 47 liters	
Maximum expiratory flow rate	8 28 liters	

Age	*Maximum Volume of One Respiration (crying)*
1 day of birth	160 ml
2	171
3	136
4	181
6	147
8	173
10	149
Adult	3500

Fig 21 Vital capacity in newborn and adult (Deming J and Hanner J P Respiration in Infancy *Am J Dis Child* 51 823 1936)

pressed in milliliters or liters of volume and centimeters of water pressure It has been shown that in the infant the compliance is less than in the adult

Oxygen Consumption and Carbon Dioxide Elimination In the newborn, the rate of oxygen consumption is slightly higher than carbon dioxide elimination (Fig 23) However both these rates are considerably higher per kg of body weight than in the adult, perhaps accounting in part for the rapid onset of hypoxia and hypercarbia in the newborn infant (Fig 24)

Immaturity of Respiratory Centers Periodicity of respiration is observed frequently in infants and is a depression of respiration resulting from immaturity of the respiratory centers Sedatives in the premedication tend to exaggerate it

Decrease in Body Temperature In cachectic or very young infants, a decrease in body temperature may produce an apnea of long duration Therefore, these patients should be kept in a heated environment to maintain normal body temperature during the preanesthetic, anesthetic, and postanesthetic periods Sedative drugs should not be given An exception is seen in some infants with congenital heart disease who can be carried to a low temperature without the occurrence of apnea

Inefficiency of Respiratory Muscles

Diseases Among diseases causing an inefficiency of respiratory muscles are poliomyelitis myasthenia gravis and congenital amyotonia Artificial respiration, tracheostomy, and tracheal aspirations may be necessary to improve pulmonary ventilation before anesthesia Sedative drugs should be omitted Many of these patients, although apparently cured, will develop intercostal muscle paralysis in the light stages of anesthesia Postoperatively, the respiration should be watched closely, and tracheal aspirations performed when the cough reflex is suppressed

Injuries An Erb-Duchenne paralysis is a birth injury of the third, fourth and fifth cervical nerves involving their branches to the phrenic nerve (Fig 25) The paralyzed diaphragm elevates on inspiration on the affected side and descends on inspiration on the intact side Consequently, in all cases with a typical Erb Duchenne position of the upper limb, chest fluoroscopy should be done before anesthesia Fortunately, the paralysis seldom lasts longer than the first three weeks of life, and for this reason, any elective surgery should be postponed

The dysfunction is ordinarily minimal Omission of sedatives in the premedication and employment of endotracheal technic to assist respiration during anesthesia preserve pulmonary function, however, postoperatively hypoxia must be prevented

Limitation of Movements of the Thorax

Kyphosis Kyphosis of the spine can reduce the size of the thoracic and abdominal cavities and in the extreme stage the ribs impinge on the pelvis This not only impedes the movement of the ribs but also restricts measurably the diaphragmatic movement For the most part there is a gradual increase in the size of the bony thorax and the breathing is largely inter-

PULMONARY CIRCULATION

Efficient pulmonary function depends upon the adequacy of alveolar ventilation diffusion of gases across the pulmonary membrane, and pulmonary capillary blood flow The latter is dependent upon right ventricular output and bears a close relationship to left ventricular output or systemic circulation In uncomplicated cases an efficient systemic circulation usually means an adequate pulmonary capillary blood flow

FACTORS AFFECTING PULMONARY PHYSIOLOGY

Preanesthetic pulmonary evaluation must depend largely on the clinical estimation since many of the pulmonary function tests done with pneumotachograph plethysmograph or spirometer have not reached a practical point in pediatrics

The anesthesiologist should be conversant with the history, physical examination and x-ray examination which led to the diagnosis of pulmonary complications He should have a knowledge of pulmonary complications and their effect upon respiratory function The following major classifications will be used to describe these complications

- Depression of respiratory centers
- Inefficiency of respiratory muscles
- Limitation of movements of the thorax
- Limitation of movements of the lungs
- Pulmonary diseases
  - Decrease in functioning lung tissue
  - Obstruction to respiration

Depression of Respiratory Centers

Increased Intracranial Pressure or Cerebral Trauma Patients with this disease may have hypoxia and hypercarbia arising from their slow and shallow respiration In fact they may require artificial respiration before arriving in the operating room therefore drugs which might further depress the respiration should be omitted in the premedication

Metabolic Alkalosis Metabolic alkalosis from vomiting or from prolonged gastric suction causes a compensatory slow shallow respiration In such patients with depressed respiration sedatives should be omitted from the premedication since further depression may threaten oxygenation However during anesthesia hyperventilation in the presence of an endotracheal tube which reduces the dead space must be avoided otherwise an operative or postoperative alkalotic tetany can readily occur

Scleroderma This hardening of the skin may occur in infants and thereby limit excursions of the thorax Consequently, adequate pulmonary ventilation must be maintained before, during, and after anesthesia

Sclerema Sclerema is a hardening of the muscles in the infant, which gradually extends up from the buttocks, involves the upper extremities and later the muscles of the thorax, limiting to a marked extent the movement of the thorax

Abdominal Distention Severe abdominal distention is one of the most frequent causes of restriction in the movement of the diaphragm (Fig 26)

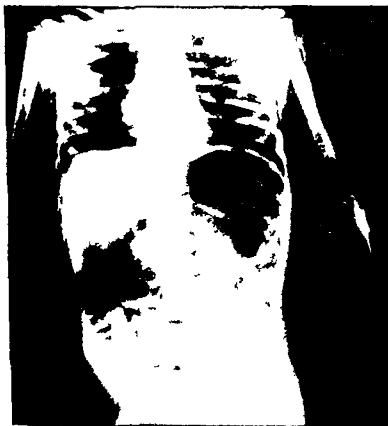


Fig 26 Dilated stomach

Infants may be born with a tremendous distention from a rupture of the intestine with peritonitis in utero In these patients the abdomen is often tense, and there is marked elevation of the diaphragm with severe restriction in its movement Compensatory enlargement of the bony thorax often occurs With this increased abdominal pressure there may be an elevation of venous pressure It is surprising how well these patients accommodate gradually to extreme abdominal distention and live with a reduced respiratory function In some instances, the abdomen may be severely distended

costal These patients should have minimal sedation The management of the anesthetic period is difficult, and if depressant drugs are used during the anesthesia assisted respiration through an endotracheal tube may be beneficial throughout the procedure Postoperatively, these patients are prone to respiratory infections but they are usually old enough to co operate and to do deep breathing exercises



Fig 25 High right diaphragm with phrenic nerve paralysis

Fortunately one does not often see such a respiratory cripple today because of the early diagnosis of the kyphosis at which time corrective measures are adopted

Pectus Excavatum Thoracic deformities such as pectus excavatum or funnel chest, may in some circumstances interfere with the expansion of the thorax However, the degree of pulmonary dysfunction is ordinarily minimal (See also p 50)



Fig 27 Large heart of the newborn limiting lung movement

strained by the elastic recoil of the lungs but the patient becomes gradually cyanotic unless artificial respiration with slight positive pressure is instituted Here oxygenation is provided by minimal pulmonary ventilation

In two cases of bilateral pneumothorax diffusion respiration with oxygen was maintained for a few hours and the gases were withdrawn gradually from the pneumothorax through a needle by removing small increments of air, about 10 ml at a time It was fortunate that in both patients the holes in the lung tissue sealed spontaneously and pulmonary ventila-

but has lost the abdominal rigidity of peritonitis so that the movement of the diaphragm is not restricted

Preoperatively, patients with abdominal distention should have a stomach tube inserted to remove any gases or fluids Prior to intubation, these patients should breathe high oxygen concentrations and respiration should be assisted gently during surgery If there is a high intra-abdominal pressure which is maintaining an adequate venous pressure, the opening of the abdomen and the escape of the bowel may cause an acute collapse of the patient therefore, blood should be given intravenously At times, calcium gluconate 100 mg preceded by intravenous atropine 0 06 mg may be necessary to maintain adequate circulation However, these measures may not be sufficient, and it may be essential for the surgeon to replace the eviscerated bowel in order to increase the venous pressure Signs of this circulatory failure are often made evident by marked pallor of the patient and a severe bradycardia

Following surgery the diaphragm does not return immediately to its normal lower level and postoperatively these patients may require oxygen therapy (maximum 40 per cent) for some days

Limitation of Movements of the Lungs

Heart Disease In congenital or acquired heart disease, the failing heart may become extremely large and occupy a considerable volume of the thorax as may extensive pericardial effusion thereby definitely limiting the movement of the lungs (Fig 27)

Fluid in the Pleural Space Sometimes the pleural space will be filled with fluid This may be from secretions blood, or chyle

Spontaneous or Traumatic Pneumothorax Pneumothorax is caused by rupture of an alveolus and may originate from vigorous crying or from overactive artificial respiration at birth It may accompany emphysema of the lungs

A simple pneumothorax is not as dangerous as a positive pressure one in which the gases leak out through a hole in the lung into the pleural cavity and cannot return through the same opening The pleural pressure therefore will rise gradually and even displace the mediastinum thereby embarrassing the circulation (Fig 28) As a rule the diagnosis is made by the gradual protrusion or enlargement of the thorax and gradual decrease of respiratory excursion on that side

In some instances the pneumothorax may be bilateral If so the thorax seems to be enlarged and to move freely on inspiration since it is not re-



Fig 29 Left congenital diaphragmatic hernia with shift of mediastinum to right and minimal bowel shadows in abdominal cavity

The management of the anesthesia requires extreme care, since increased intrapulmonary pressure may increase the pneumomediastinum This is another instance in which the oxygenation should be maintained during anesthesia by gentle inflation of the lungs even at the expense of a hypercarbia

Congenital Diaphragmatic Hernia This usually occurs in the left chest, and there is frequently no expansion of the left lung, the opposite lung being hyperdistended (Fig 29) These patients may have had bouts of cyanosis, but generally they appear to be in a remarkably good condition and well oxygenated In fact, they often have a deceptively healthy pink color which may be due to a hypercarbia Occasionally these patients are

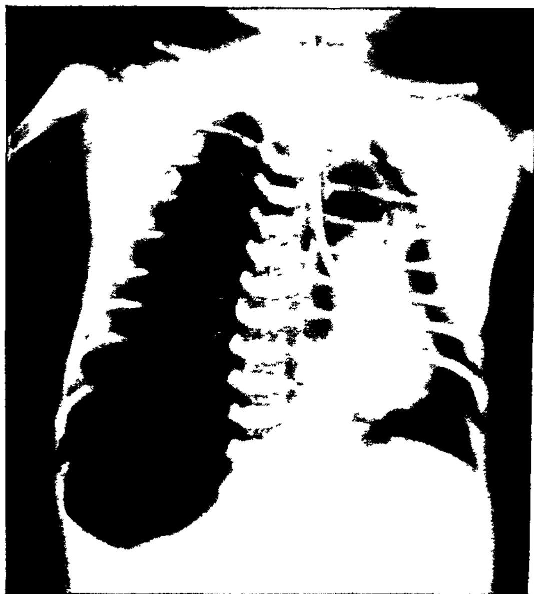


Fig. 28 Right positive pressure pneumothorax causing mediastinal shift to left in the newborn

tion was restored gradually Both these patients had hyperpnea postoperatively, probably due to the hypercarbia

Pneumomediastinum This is due to the accumulation of air in the mediastinum It may have its origin in vigorous crying or overactive artificial *respiration* or it may even arise from a surgical procedure which causes trauma to the lung tissue The diagnosis can be confirmed by a lateral x-ray of the chest in which the accumulation of air is seen usually just beneath the sternum This is a serious condition which may not only embarrass respiration but is even more likely to embarrass circulation



Fig 31 Microscopic section of newborn lung Colored portions represent hyaline membrane lining alveoli

rushed to the operating room in extremis, and, often dramatically lifesaving, an emergency thoracotomy is done to permit the escape of distended loops of bowel

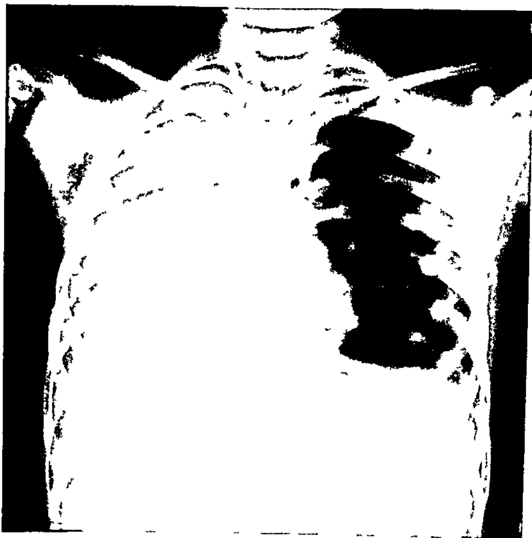


Fig 30 Atelectasis of right lung with mediastinal shift to right

Pulmonary Diseases

Decrease in Functioning Lung Tissue

Atelectasis Most frequently a child who cries at birth opens up his alveoli and the cyanosis disappears He then becomes pink, very active and has a rapid heartbeat with good expansion of his thorax on inspiration Other infants at birth do not cry or may have a very feeble cry Re-



Fig 31 Microscopic section of newborn lung Colored portions represent hyaline membrane lining alveoli

maining cyanotic, they may have a slow heartbeat and the thorax may not expand on inspiration In fact the contraction of the diaphragm may bring about a protrusion of the abdomen and a marked retraction of the thorax on inspiration X ray of the chest shows increased opacity of the lung fields (Fig 30) Sometimes even high oxygen concentrations produce no improvement in the cyanosis most of the oxygen being drawn into the stomach on inspiration The remainder goes into the trachea and bronchi a little of it reaching the pulmonary circulation Some infants do not show this extreme picture but do have some cyanosis in the feet and hands An attempt has been made by pediatricians to improve the pulmonary physiology before proceeding with the surgery This treatment may consist of oxygenation and the insertion of a tiny catheter into the trachea to promote coughing or painful stimulation to promote crying These measures tend to expand the small alveolar ducts and open up the areas of atelectasis The best results have been obtained with the newborn who shows areas of atelectasis by x ray which seem to disappear with the above treatment This particular group often survive prolonged operations and have a comparatively uneventful recovery period

Another method of improving the condition of the severely cyanotic patient is to give oxygen with intermittent positive pressure

Hyaline Membrane This complication is more common in the premature than in the full term infant and is also more prevalent in infants delivered by Cesarean section Hyaline membrane is often associated with secondary or resorption atelectasis (Fig 31) The periphery of the lungs is most heavily affected

Figures 32 and 33 represent an abnormal newborn with a restrictive lesion reduced residual capacity and reduced vital capacity Such a lesion would also show no reduction in the timed vital capacity

Other pulmonary conditions such as previous lobectomy cysts (Fig 34) or tumors of the lungs hemorrhage into the lung (seen occasionally in the newborn) pneumonia (Fig 35) lung abscesses bronchiectasis fibro cystic disease of the lung pulmonary congestion pulmonary edema (Fig 36) and sarcoidosis reduce the amount of functioning lung tissue and interfere with diffusion of gases across the pulmonary membrane

Obstruction to Respiration

Perhaps no other impediment to pulmonary physiology occurs as frequently as obstruction to respiration

	Normal	With Respiratory Distress	
FRC	70 ml	40 ml	−43%
TV	15 ml	13 ml	−13%
Rate	34/min	64/min	+88%
MV	498 ml	872 ml	+75%
VC	140 ml	70 ml	−50%
AV	355 ml/min	250 ml/min	−30%
FDS	5 ml	8 5 ml	+70%
pCO_2	32 mm Hg	40 mm Hg	+25%
Compliance	5 ml/cm H_2O	1 5 ml/cm H_2O	−70%
PW	1450 gm cm	5800 gm cm	+300%
CO_2 elimination	14 ml/min		
O_2 consumption	12–20 ml/min		

Fig 32 Comparison of pulmonary function tests in normal and respiratory distressed newborn (Cook C D Lucey J F Drobaugh J E Segal S Sutherland J M and Smith C A Apnea and Respiratory Distress in the Newborn Infant Physiologic Background Resuscitation and Supportive Technics, *New England J Med* 254 566 1956)

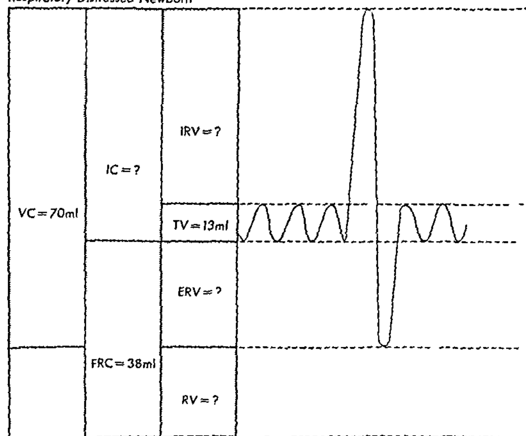


Fig 33 Diagram of respiratory volumes in a respiratory-distressed newborn (Adapted from Cook C D Lucey J F Drobaugh J E Segal S Sutherland J M and Smith C A "Apnea and Respiratory Distress in the Newborn Infant Physiologic Background Resuscitation and Supportive Technics *New England J Med* 254 565 1956)



Fig 34 Cyst of left lung

Oronasopharyngeal Obstruction Posterior or the rare anterior choanal atresia or stenosis occludes the nasal air passage (Figs 37 and 38) If it is bilateral oral or mouth breathing is mandatory Such an infant is admitted usually as an emergency in the first few days of life To prevent the tongue from adhering to the hard palate (Fig 39) the airway is kept patent by either opening the mouth keeping the child crying or inserting an oropharyngeal airway (Fig 40) The corrective operation is done as soon as possible and patency of the nasal air passages is established



Fig 35 Usual type of diffuse widespread pneumonia seen in newborn

Increased secretions severely fractured nose, deviated septum polyps and other tumors may also cause varying degrees of nasal obstruction

When children who are subject to obstructive allergic rhinitis (hay fever) are to be anesthetized an antihistaminic should be given preoperatively In addition ether because of its sympathomimetic properties is selected as the anesthetic agent

Some children are prone to epistaxis If this is not related to hemorrhagic disease it may be caused by ulceration of the nasal septum Insertion of suction catheters or nasal endotracheal tubes should be avoided

Children up to the age of about twelve years may have hypertrophy of the adenoid tissue with consequent obstruction to the nasal airway The

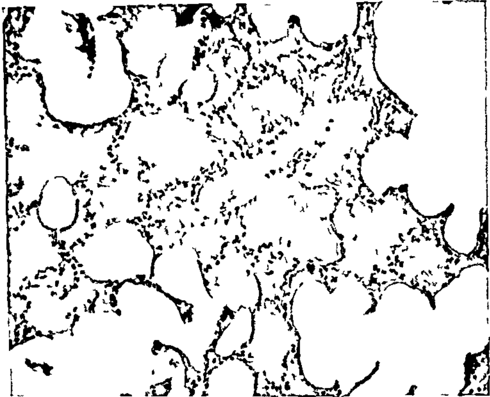


Fig 36 Microscopic section of lung with pulmonary edema



Fig 35 Usual type of diffuse widespread pneumonia seen in newborn

Increased secretions severely fractured nose, deviated septum polyps and other tumors may also cause varying degrees of nasal obstruction

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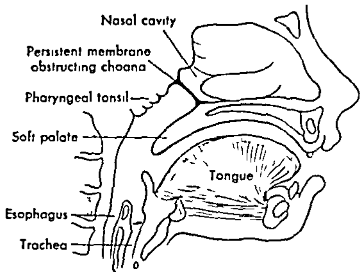


Fig 37 Sagittal section of upper respiratory passages showing choanal atresia



Fig 38 Infant with choanal atresia showing retraction of chest and indrawing of lips corrected by oropharyngeal airway

danger, however of obstruction from adenoidal tissue is seen rarely until the patient is at least one year old

A child may push a foreign body into his nose We have seen numerous instances in which one nostril has been blocked by a foreign object Most

tonsillar abscess may be encountered in the infant or child If such an abscess has to be incised and drained, complete obstruction to respiration may occur early in anesthesia

Foreign bodies, aberrant thyroid tissue, tumors, and angioneurotic edema may also block the pharyngeal airway

Laryngeal Obstruction Laryngomalacia, characterized by incomplete development of the cartilages of the epiglottis, is frequently seen in a children's hospital These children have an inspiratory obstruction, since the epiglottis, aryepiglottic fold, and arytenoid are flaccid and are aspirated into the larynx on inspiration Usually, this condition subsides by the middle of the second year of life

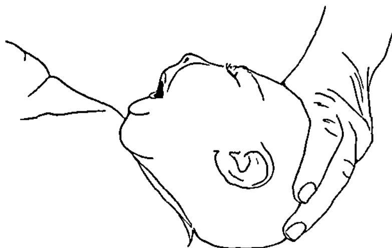


Fig 41 Lateral view of infant with Pierre Robin syndrome

An alarming condition called epiglottitis an infective process causing great enlargement of the epiglottis may be seen in children admitted to the hospital as emergencies Diagnosis is made usually from a respiratory obstruction and the voice which sounds as if the back of the throat were full of food In confirmation direct laryngoscopy discloses a huge edematous supraglottic mass Tracheostomy is mandatory Even light general anesthesia or attempted intubation may prove fatal, and local anesthesia is preferable The tremendous enlargement of the epiglottis is caused by edematous fluid extravasating into loose areolar tissue on the anterior surface of the epiglottis This edema is not pronounced on the posterior of the epiglottis because of the rigidly adherent mucous membrane (Figs 42 and 43)

Numerous papillomas of the vocal cords may occur in some children These have to be removed periodically to prevent serious obstruction to

of these have been detected accidentally when passing a nasotracheal tube which pushes the foreign body into the pharynx

Pharyngeal Obstruction Some anatomical lesions and anomalies such as cysts and tumors at the base of the tongue obstruct the oral airway Mongoloids have a small mouth (microstomia) and in some cases have a hypertrophy of the tongue



Fig 39 Oral obstruction from valve like action of tongue against hard palate

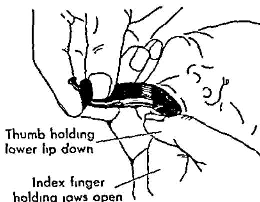


Fig 40 Method of insertion of oral airway

The edentulous infant breathes nasally If the nasal air passages are partially blocked, as soon as the infant is anesthetized the tongue adheres like a valve to the hard palate and he becomes obstructed Pressure of the anesthesiologist s finger in the submandibular area will increase the frequency of this obstruction Instead, the head should be extended and the mandible separated from the maxilla opening the oral cavity

Pierre-Robin syndrome is a congenital anomaly of the newborn, characterized by a hypoplastic mandible and a glossoptosis (Fig 41) This backward displacement of the tongue causes considerable respiratory ob struction The obstruction disappears by the end of the second year

Most children breathe freely even though they have hypertrophied ton sils However, in the very narrow faced child, hypertrophied tonsils can meet in the midline and cause evident obstruction soon after commence ment of anesthesia

Although relatively uncommon today, a large retropharyngeal or peri

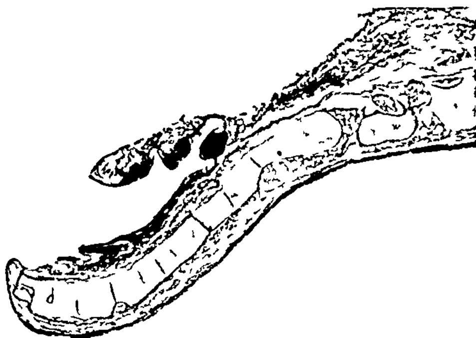


Fig 42 Sagittal section of infant's epiglottis colored portion representing cartilage

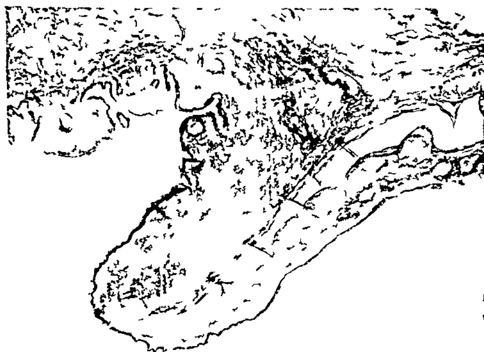


Fig 43 Sagittal section of infant's epiglottis showing marked edema anteriorly

respiration In fact, it may be dangerous to give them any sedatives without first viewing the larynx and determining the magnitude of the tumor These papillomas tend to disappear spontaneously at puberty

Paralysis of the vocal cords, tuberculosis, laryngotracheobronchitis, and foreign bodies may reduce the size of the glottic aperture

In some instances, a laryngeal web or subglottic web immediately below the level of the cricoid cartilage is seen in the newborn

At times, edema of the larynx following instrumentation or diphtheria is seen In the newborn, the glottic aperture has an anteroposterior diameter of 7 mm and a width opposite the posterior commissure of 4 mm Edema of 1 mm will cause a marked reduction of the 14 sq mm aperture of the glottis to 5 sq mm Subglottic edema in the region of the cricoid, which is the only complete cartilaginous ring in the trachea may cause a severe respiratory obstruction

Certain drugs such as barbiturates or cyclopropane, too early insertion of an oropharyngeal airway or regurgitation of secretions may bring about a glottic spasm Some of these spasms are alarmingly sustained Ether at times will produce a laryngospasm but as soon as the irritating ether is removed the patient breathes, so, on the whole it does not produce the alarming sustained complication that occurs with barbiturates or cyclopropane

Tracheal Obstruction The trachea may be partially occluded by foreign bodies secretions blood acute tracheitis, diphtheria, enlarged thyroid gland lymphoma, cystic hygroma or mediastinal tumor

Tracheal stenosis is another complication which may be encountered usually as the sequel to a high tracheostomy performed in the presence of local infection

Low down in the trachea just above the carina a congenital anomaly in the form of a vascular ring may encircle the trachea completely, causing obstruction during not only inspiration but also expiration Since the anomaly is present from birth noticeable hyperdistention of the alveoli may occur Both lungs may be emphysematous, a condition caused by the obstruction to expiration with consequent air trapping

Bronchial Obstruction Patients with bronchiectasis and considerable secretions are best prepared by a period of treatment which includes deep breathing exercises postural drainage, and tracheal aspirations The patient operated upon in the early afternoon has often had an opportunity to clear out the secretions from the respiratory tract These secretions may

be so copious that following the induction of anesthesia and the intubation a polyethylene catheter should be passed down the trachea to promote coughing and further evacuation of secretions The patient should at this time be in the Trendelenburg position with strong suction available, for the secretions are sometimes thick and tenacious Between aspirations the suction tube should be cleansed in water and the patient allowed to breathe high oxygen concentrations It is of considerable benefit to aspirate the trachea through the endotracheal tube at frequent intervals during surgery since a far better cough reflex is present at this time than will be present postoperatively, although postoperative tracheal aspirations are also very beneficial

Asthmatic patients may have thick tenacious secretions occluding many bronchi Prior to elective surgery a period of treatment with bronchodilators and intermittent positive pressure breathing may improve the general condition of the patient besides having a specific effect upon the pulmonary function Patients so treated may show a marked improvement in their timed vital capacity, maximum breathing capacity and reduction in their residual capacity However, sometimes surgery is urgent, and in these instances we employ an adrenergic like agent ether

Foreign bodies will at times occlude a bronchus completely and at other times there will be a ball-valve effect wherein some of the gases escape into the lungs on inspiration and the lungs become hyperdistended with gases

Rarely bronchiolar spasm occurs due to stimulation of the trachea by irritating gases or occasionally from administration of cholinergic drugs such as neostigmine (Prostigmin) However, adequate atropine in the premedication usually prevents this bronchoconstriction

Occasionally atresia or stenosis of a bronchus may develop and is usually diagnosed from the bronchogram (Fig 44)

Another possible cause of obstruction is bronchomalacia Although rare the anesthesiologist should keep it in mind as a cause of complete occlusion of a bronchus On one occasion during the removal of a cyst of the lung the opposite bronchus became completely occluded due probably to a shift in the mediastinum On another occasion when the bronchologist was examining the trachea he found that inflation of the lungs was impossible until the infant was changed from the flexed to the extended position (Fig 45)

Pulmonary function tests on infants and children with these obstruc-

and feet It may be due to a mild degree of pulmonary insufficiency, since positive pressure breathing with an inspiratory pause of 2 or 3 seconds at 10 cm of water pressure may cure it Third, there is generalized cyanosis, indicating a severe degree of respiratory insufficiency or congenital heart disease

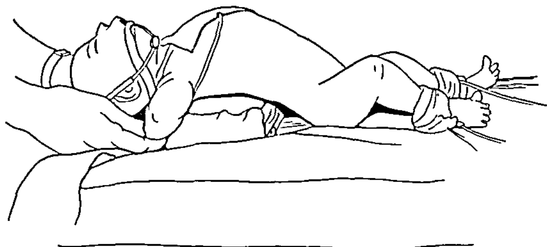


Fig 45 Shoulder pad providing cervical and upper thoracic extension with improvement of airway Slocum tube is strapped in place with adhesive tape

Cyanosis of respiratory origin in older children is generalized and denotes severe pulmonary insufficiency

2 *What is the rate of respiration?* Considerable prognostic value has been placed upon the respiratory rate of the newborn There are three groups in the newborn first, those who breathe approximately at the rate of 40 per minute from birth on without significant fluctuation second, those who breathe over 60 times per minute in the first hour and subsequently decrease to normal levels, and third, those who breathe around 40 per minute at birth then increase to over 60 per minute and remain at a high rate for 2 or 3 days Many of the premature infants belong to this third group in which the prognosis is generally unfavorable

A rapid respiratory rate due to pulmonary insufficiency in older children is usually due to interference with the diffusion of gases across the pulmonary capillary membrane

3 *What is the rhythm of respiration?* Normal infants have a regular rhythm during the first 2 or 3 days of life, and an irregular periodic breathing by the end of the first week This periodicity continues for weeks Periodicity of breathing immediately after birth suggests an insufficiency of respiration and may be due to one of the following depression of the

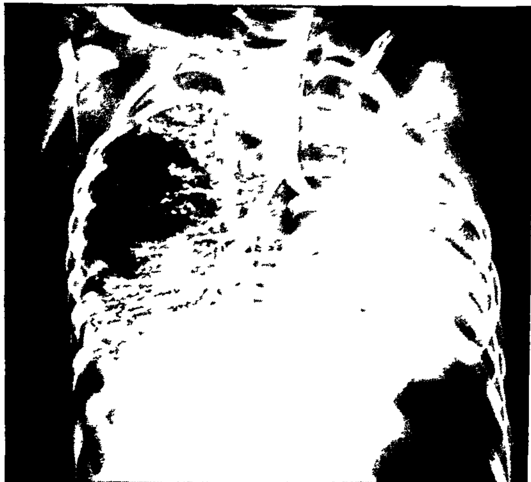


Fig. 44 Bronchogram in four year-old showing stenosis of the left bronchus with atelectasis of the left lung

tive lesions would show a reduced timed vital capacity but no reduction in vital capacity a reduced breathing capacity and an increased residual capacity

On the whole, the anesthesiologist must depend upon certain clinical signs for an assessment of the pulmonary system What are the clinical signs and what simple diagnostic methods are available to the pediatric anesthesiologist?

1 *Has the patient cyanosis?* In the newborn infant there are three types of cyanosis First there is localized cyanosis of the head—unrelated to respiration—which is attributed to pressure during pregnancy or delivery Resembling the local traumatic asphyxia of crush injury this type of cyanosis does not respond to oxygen therapy and disappears spontaneously Second, there is acrocyanosis which is confined to the hands

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respiratory centers from large dosages of sedatives administered to the mother immediately before delivery, cerebral injury, and low body temperature The most frequent cause is immaturity of the respiratory centers and lungs of a premature infant The premature infant requires constant attention Movement or feeding may bring on an apnea in a very small premature, and gentle massage or stimulation may be required to reinitiate respirations and avoid a fatal apnea

4 *What is the shape of the thorax?* Is it the normal cylindrical shaped thorax of the infant with the horizontal ribs and expanded lungs? Is it the bell-shaped thorax of the infant with the declined ribs and unexpanded lungs?

5 *Is there dyspnea?* This can be determined by the simultaneous examination of the costal and diaphragmatic components of breathing The most practical test to determine the type of dyspnea is to apply a close fitting mask and breathing bag to the face A normal tidal volume with a prolonged emptying or filling of the breathing bag denotes an obstruction to respiration Such a lesion would give a reduced timed vital capacity A reduced tidal volume without a prolonged emptying or filling of the breathing bag denotes a restriction to respiration Auscultation of breath sounds and percussion are also part of the anesthesiologist s means of diagnosis

Confirmatory information relating to the above-mentioned clinical signs may be obtained from the report of the patient's chest film

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thoracic cavity Weighing 19 5 to 23 5 gm initially, during the first year of life the heart weight doubles At birth both ventricles are of equal weight, for the walls are of equal thickness however, during the first six months, the left ventricle grows more rapidly and becomes twice the weight of the right ventricle At birth, as in adult life, the right atrium is larger than the left

As a rule the ductus arteriosus is obliterated anatomically within the first two months of life, but closes functionally soon after birth The foramen ovale is thought to be sealed anatomically within the first year, although it is nonfunctioning as soon as the pressure in the left atrium is greater than in the right atrium, occurring usually with the first breath or cry of the infant

The ductus venosus, in utero carrying most of the blood from the umbilical vein into the inferior vena cava closes anatomically in less than one month after birth, but closes functionally as soon as the umbilical cord is clamped

BLOOD VESSELS

In the newborn and especially in the premature the major blood vessels have developed to a greater maturity than the peripheral vessels, which do not exhibit the characteristic multiplicity of finer loops until a few weeks following birth At birth however, the largest of these peripheral vessels form an abundant anastomotic network, capable of efficient gaseous transportation and exchange

NORMAL PHYSIOLOGY

The pediatric anesthesiologist should monitor the cardiovascular system continuously throughout the operation But to do this intelligently, he must be familiar with physiological values and be able to interpret them

COURSE OF CIRCULATION BEFORE AND FOLLOWING BIRTH

Antenatal (Fig 46)

From the placenta the majority of oxygenated blood passes through the umbilical vein shunting into the sinus venosus where it is joined by venous blood of the portal vein This mixed blood enters the inferior vena cava and flows into the right atrium A large portion of the blood from the inferior vena cava passes to the left atrium through the patent foramen

CHAPTER 5

EVALUATION OF THE CARDIOVASCULAR SYSTEM

Evaluation of the cardiovascular system is a difficult task for the pediatric cardiologist This difficulty is magnified for the pediatric anesthesiologist who must not only understand the significance of the cardiologist s examination and diagnosis but then in cooperation with the surgeon guide the patient through a perilous operative and immediate postoperative period

The following information gathered from our associates from the literature and from our own experience can serve only as a guide in estimating the condition of the cardiovascular system However a review of the cardinal anatomical and physiological data is essential to good anesthesia

NORMAL ANATOMY

Familiarity with the normal anatomy of the circulation provides a basis for understanding the physiology On the whole, anesthesiologists are much better acquainted with the cardiovascular system of the child than of the infant For this reason the larger part of the ensuing discussion will be devoted primarily to the anatomy of the infant

HEART

The shape of the newborn heart is more conical than that of the adult and it occupies a more oblique position in the chest due to a high diaphragm

At birth, the heart is relatively large filling a considerable part of the

small residual continues the tour of the lesser circulation via the pulmonary circuit to the left ventricle

To summarize, both the right and left ventricles are pumps of the systemic circulation, carrying blood to all parts of the body, but particularly to the umbilical arteries and placenta for oxygenation (Fig 47)

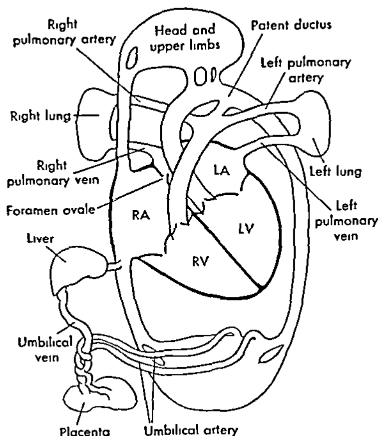


Fig 47 Outline diagram of antenatal circulation (Reprinted by permission of the publishers and The Commonwealth Fund from Helen B Taussig *Congenital Malformations of the Heart* Cambridge Mass Harvard University Press Copyright 1947 by The Commonwealth Fund)

Postnatal

Closure of the umbilical arteries elevates the aortic pressure while pulmonary expansion and ventilation decrease the resistance in the pulmonary vascular circuit lowering pulmonary arterial pressure Closure of the umbilical vein increases blood flow through the portal vein and at the same time the sinus venosus shuts Constriction of the ductus arteriosus and subsequent rise in pressure in the left atrium, closing the foramen ovale, separate the heart functionally into the right and left sides The right ventricle is now the pump for the pulmonary circulation and the left ventricle the pump for the systemic circulation

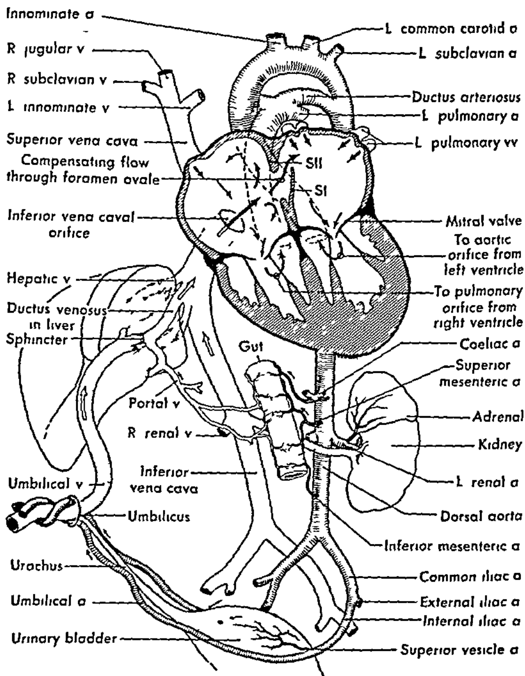


Fig 46 Diagram of antenatal circulation (From *Human Embryology* by Bradley M Patten 1953 Courtesy of Blakiston Division McGraw Hill Book Co)

ovale thence into the left ventricle and aorta, supplying the coronaries and cerebral circulation with oxygenated blood The remainder of the blood in the right atrium derived from the inferior and superior venae cavae, enters the right ventricle and pulmonary artery, with most of it directed primarily into the aorta through the patent ductus arteriosus A

Whether auscultatory or oscillatory methods are utilized, these recommendations are obligatory for proper values to be obtained in this essential measurement Recommended cuff widths are

0–1 year	2 5 cm
1–4 years	5 0 cm
4–13 years	8–9 cm

The normal systolic blood pressures are shown in Figure 49 The diastolic pressure is ordinarily about 35 mm Hg below the systolic

Age	*mm Hg*
Newborn	20–60
1st week	60–80
1st year	80–85
1–6 years	85–90
6–12 years	90–105

Fig 49 Average systolic blood pressure from birth to twelve years

Venous

Venous pressure can be approximated by lowering the intravenous infusion bottle to the point where venous blood just begins to flow back into the infusion set At this point, the height of the fluid level in the bottle above the right atrial level is the venous pressure normally 1 5–6 mm Hg or 2–7 cm of water

BLOOD VOLUME

The normal blood volume of infants and children is about 75–90 ml per kg of body weight with a considerable portion of the blood volume in the visceral veins of the abdomen At birth there is a poor distribution of blood in the periphery where the capillaries are smaller and fewer in number Blood volume must be maintained if shock is to be avoided Therefore if blood loss is anticipated or the patient is anemic matched blood must be obtained and a cut down performed before surgery (Fig 50)

CIRCULATION TIME

Circulation time in infants has been measured by many investigators using varied technics It is not surprising, considering the different circulatory routes which they have tested that the circulation times recorded should vary all the way from 4 4 to 15 seconds

HEART RATE

The cardiac rate of a normal infant has considerable range Vagal stimulation may cause a bradycardia, activity may cause a tachycardia An approximation of heart rate in the infant is listed in Figure 48

Fetal	130–160	2 weeks	133
Birth	180	2 months	130–133
10 minutes	170	6–12 months	113–127
1 hour	134–136	1–2 years	100–110
24 hours	123–136	2–4 years	96–108
1–8 days	124–130	4–10 years	80–100

Fig 48 Normal heart rate from fetal life to ten years (Smith C A *The Physiology of the Newborn Infant* 3rd ed Charles C Thomas Publisher Springfield Ill 1959)

CARDIAC RHYTHM

Sinus arrhythmia characterized by an increase in heart rate during inspiration usually is not seen during the first year of life when the heart rate is comparatively rapid Appearing during the second year when the heart rate is slower it is exaggerated by deep breathing, but disappears with tachycardia resulting from crying from anticholinergic drugs, or from sympathomimetic drugs such as ether However extrasystoles are fairly common during the first three months of life

INTENSITY OF HEART SOUNDS

Heart sounds are well heard through the thin chest wall of the newborn Any diminution suggests some cardiac dilatation and diminished force of myocardial contraction and can be interpreted as reduced cardiac output

A continuous, reliable, and sensitive cardiac monitor in the form of a stethoscope strapped to the chest of the patient and connected to the ear of the anesthesiologist is used routinely in all cases

BLOOD PRESSURE

Arterial

Accuracy of the measurement of blood pressure in the periphery is contingent upon (1) proper cuff width and (2) complete extremity encirclement by the inflatable portion of the cuff

dehydrocholic acid (Decholin) method, had an average circulation time of 10 5 to 11 9 seconds This time was reduced by 1 to 3 seconds when children were in the erect position All the quoted circulation times for children are much shorter than in the adult, generally thought to be about 22 seconds

BLOOD VOLUME FLOW

This represents to a large extent the efficiency of the circulation, however, unfortunately, there are no definite data on the volume flow of blood It has been estimated that the ventricle of the heart of a 3 5 kg infant should pump about 520 ml per minute, but estimations by Wiggers give an output of only 240 to 350 ml per minute The stroke volume in these cases is about 4 5 to 5 ml

From these estimates, the newborn heart has a blood volume flow per minute of approximately 135 ml per kg of body weight, as contrasted to the adult flow of 62 ml per kg

The high arterial blood volume flow in the newborn could be postulated from Poiseuille's law

$$\text{Blood volume flow} = \frac{\pi r^4 (P_1 - P_2)}{8 \times \text{viscosity} \times \text{length}} \text{ measured in dynes/cm}^2$$

r = radius of the vessel
P = pressures measured at two different parts of the vessel
viscosity = viscosity of the blood
length = length of the blood vessel

It is obvious that r^4 is the most dominant factor If, for example, all other parts of the equation remained constant, then increasing the radius of a blood vessel from 1 mm to 2 mm would increase the flow sixteen times Since, anatomically, the great vessels of the newborn are relatively larger than those of the adult the large radius of these vessels more than compensates for the increased viscosity of the newborn infant s blood

Foremost in regulating the blood volume flow in the veins is the vis a tergo, the propelling force imparted to the arterial, capillary and venous blood by the strength of the myocardial contraction

Other factors affecting the venous blood volume flow are the intrathoracic negative pressure caused by the elastic recoil of the lungs, the changes in intrathoracic pressure brought about by breathing especially inspiration known as vis a fronte and which is particularly high in the infant with respiratory distress the attraction of venous blood to the heart

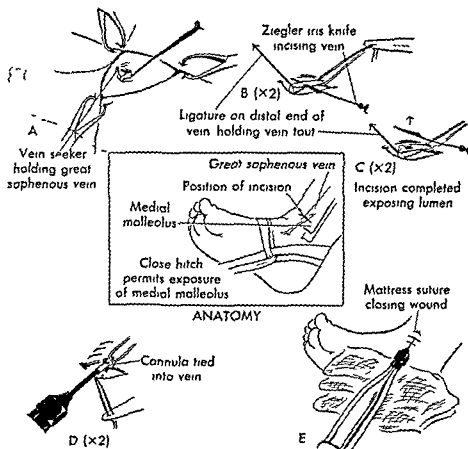


Fig 50 'Cut-down procedure

One of these studies, by Lawrence Slobody et al, found no connection between circulation time in these infants and activity, crying sex, color, or weight Three premature infants studied had circulation times close to the average for newborns

Circulation time in children from three to fifteen years seems to remain fairly constant increasing only slightly with age and related more to weight than to height In the series quoted in Figure 51 no relation was found between circulation time and blood pressure, pulse or respiratory frequency One hundred and eighty-two normal children, tested by the

Age years	*Circulation Time* range (seconds)	*Circulation Time* average (seconds)
3–6	8 0–12 0	10 5
6–9	7 5–15 5	10 4
9–12	7 5–14 0	11 0
12–15	10 0–16 0	11 9

Fig. 51 Circulation time from 3 to 15 years (Decholin method)

ABNORMAL ANATOMY AND PHYSIOLOGY

METHOD OF EVALUATION

An accurate estimate of the condition of any child s cardiovascular system can be achieved only by studying his history, physical examination, and diagnostic tests reported by the pediatric cardiologist, radiologist, and pediatrician It is therefore evident that the management of the anesthesia becomes an individualized procedure for each patient, particularly the patient with an abnormal cardiovascular system

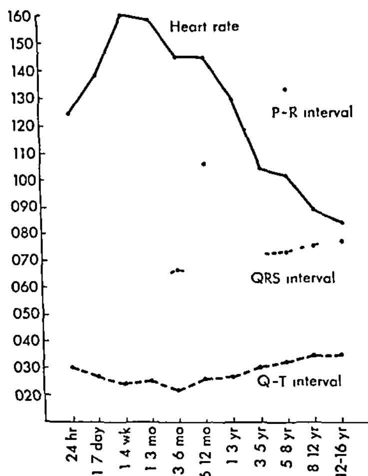


Fig 53 Diagram showing decreasing heart rate and increasing P R interval with lesser increase in QRS and Q T intervals from birth to sixteen years (Ziegler R F *Electrocardiographic Studies in Normal Infants and Children* Charles C Thomas Publisher Springfield Ill 1951)

History

The history of the patient s mother may be revealing for a hypertensive mother may have a hypertensive infant or a diabetic mother may have

by the descent of the atrioventricular junction during ventricular systole, and, finally, the propulsion of the venous blood in the extremities by voluntary muscle contraction

ELECTROCARDIOGRAM

The heart is sometimes monitored by electrocardiography in the newborn, in very ill patients, in cardiac patients, and in patients with arrhythmias Therefore, since the anesthesiologist will not have the skilled services of a cardiologist for all his difficult cases, he requires a basic knowledge of the normal electrocardiogram

Ziegler has studied extensively the normal electrocardiogram patterns in both infants and children, and from his excellent work we have gained information about the normal complex, illustrated in Figure 52 The P R

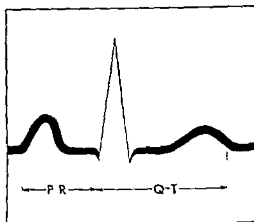


Fig 52 Normal electrocardiograph complex of infant who has a short P R interval compared with that of the adult (Ziegler R F *Electrocardiographic Studies in Normal Infants and Children* Charles C Thomas Publisher Springfield Ill 1951)

interval represents atrial activation and atrioventricular conduction while the Q T interval represents the electrical impulse producing systole of the ventricles In the newborn infant, the average P R interval is 0 099 second and the Q-T interval is 0 294 second However with age and decreasing heart rate these intervals increase and in the adult the average P-R interval is 0 20 second and the Q T interval is 0 36 second (Fig 53)

A typical electrocardiogram in the newborn shows right axis deviation a prominent Q wave in lead 2, and a R wave with lower amplitude in lead 2 than lead 3 During the first three weeks of life the T wave is sometimes absent in lead 2 (Fig 54) Between three and six months of age the electrocardiographic pattern changes to the adult type

ABNORMAL ANATOMY AND PHYSIOLOGY

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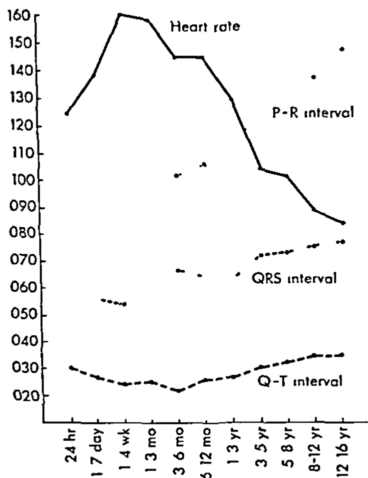


Fig. 53 Diagram showing decreasing heart rate and increasing P R interval with lesser increase in QRS and Q T intervals from birth to sixteen years (Ziegler R F *Electrocardiographic Studies in Normal Infants and Children* Charles C Thomas Publisher Springfield Ill 1951)

History

The history of the patient's mother may be revealing for a hypertensive mother may have a hypertensive infant or a diabetic mother may have

an infant with a hypertrophied heart However, the history of the patient is generally more significant Retarded development and growth, lessened activity, cyanosis, squatting, syncope, or convulsions suggest congenital cardiovascular disease

A history of rheumatic fever suggests acquired heart disease, while a background of congestive heart failure treated with digitalis warns of increased myocardial irritability Epinephrine, calcium chloride, or cyclopropane may augment this irritability On the other hand patients may have been treated with quinidine, which has the opposite effect from digitalis and decreases the myocardial irritability In these instances anesthetic agents such as ether or intravenous barbiturates may cause an abrupt fall in blood pressure

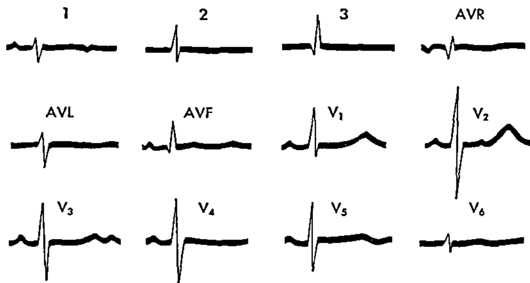


Fig 54 Diagram of typical electrocardiograph complexes of an infant in the first three weeks of life (Ziegler R F *Electrocardiographic Studies in Normal Infants and Children* Charles C Thomas Publisher Springfield Ill 1951)

It is important to note a history of previous operations on the heart For example, a previous left-sided Blalock operation indicates that the blood pressure cuff should be applied to the right arm

Physical Examination

After studying the physical examination report on the patient s chart, the anesthesiologist verifies the following points in particular on his visit to the patient Is there a normal healthy color generalized cyanosis or cyanosis localized to the upper or lower part of the body? Is the child physically underdeveloped? Is there noticeable paucity of subcutaneous fat? Do the blood vessels stand out prominently in the neck or over the

thorax? Is the front of the chest pushed forward and deformed, or does the chest exhibit pulsations? Is there clubbing of the fingers and toes? What are the blood pressure, the heart rate and rhythm?

Radiological Report

A thoracic x-ray and particularly the fluoroscopic report of the thorax relay a significant story of the dynamics of the cardiovascular system to the anesthesiologist The x-ray report of the films of the chest usually is not sufficient, and we prefer to display the films in the view box during surgery In this way, the anesthesiologist obtains a picture of the chambers of the heart and the size In addition he notes the degree of vascular engorgement in the peripheral areas of the lung, indicating diminished or increased pulmonary vascular perfusion

Hemogram

Elevated hemoglobin, red blood cell count, and hematocrit indicate a compensatory response to hypoxia Generally, the greater the degree of hemoconcentration, the greater the degree of hypoxia, and it is imperative that these patients with marked hemoconcentration be kept hydrated On the other hand some cardiac patients have hemodilution, and as a result blood transfusion may be necessary before surgery

Electrocardiogram

The child s electrocardiogram should be studied and the cardiologist's interpretation noted The anesthesiologist should be familiar with the specific electrocardiographic pattern for the cardiovascular disease involved, for only through a knowledge of particular electrocardiographic patterns can the anesthesiologist employ the ECG as a cardiac monitor during surgery

Urinalysis

The complete urinalysis record should be studied A patient with cardiovascular disability often shows albumin, concentrated urine and a few red blood cells in the urine all due to congestion of kidney glomeruli

Cardiac Catheterization

This provides information concerning

1 Pressures in the chambers of the heart and in some of the great vessels

2 Degree of oxygen unsaturation in chambers of the heart thus demonstrating the presence and/or direction of a shunt

3 Systemic flow, calculated from the following formula based on the Fick principle

$$\text{Systemic flow (ml/min)} = \frac{O_2 \text{ consumption (ml/min)} \times 100}{O_2 \text{ content of arterial blood (vol \%) minus } O_2 \text{ content of mixed venous blood (vol \%)}}$$

4 Pulmonary flow calculated as follows

$$\text{Pulmonary flow (ml/min)} = \frac{O_2 \text{ consumption (ml/min)} \times 100}{O_2 \text{ content of arterial blood (vol \%) minus } O_2 \text{ content of pulmonary artery blood (vol \%)}}$$

5 Volume of a left-to right shunt, expressed as follows

Left to right shunt (ml/min) = Pulmonary blood flow (ml/min) minus systemic blood flow (ml/min)

6 Volume of a right-to-left shunt expressed as follows

Right to left shunt (ml/min) = Systemic blood flow (ml/min) minus pulmonary blood flow (ml/min)

7 Cardiac index (cardiac output expressed in liters per sq meter of body surface) The cardiac output can then be readily compared with that of a normal child

Angiocardiography and Aortography

Angiocardiography, wherein radiopaque dye is injected into the vein and serial films of the chest are taken, demonstrates the size and shape of the heart chambers and vessels and may also confirm the presence of a right to left shunt

Aortography in which the radiopaque dye is injected into the brachial or femoral artery may confirm the presence of a left to right shunt

CONGENITAL ANOMALIES AND DEFECTS OF THE HEART AND GREAT VESSELS

Congenital anomalies of the heart and great vessels alter to varying degrees, the hemodynamics of circulation Some of these defects can be so severe as to be incompatible with life while others are amenable to surgical correction with subsequent improvement or cure To date cardiac surgeons have improved the daily existence and prolonged the life span of patients with pulmonic stenosis tetralogy of Fallot ventricular and

atrial septal defect patent ductus arteriosus, coarctation of the aorta, vascular ring, and minor degrees of transposition of the vessels The ultimate result depends to a large extent on the type of anomaly, the degree of defect, and the effect upon the circulation

Congenital heart disease may be divided into acyanotic and cyanotic types In the acyanotic type there is either no shunt or a left-to-right shunt, as occurs in atrial and ventricular septal defect, patent ductus arteriosus, anomalous pulmonary venous drainage, and coarctation of the aorta A left-to right shunt increases the pulmonary blood flow, causing a compensatory increase in pulmonary vascular resistance and pulmonary artery pressure Such increased pulmonary vascular resistance restrains the increasing pulmonary blood flow However, because of the congestion from increased pulmonary blood flow, these patients are susceptible to pneumonitis pneumonia, and chest colds explainable in part by compression of the bronchi from the engorgement, thus diminishing bronchiolar secretory drainage

Cyanotic congenital heart disease implies a right-to-left shunt These patients have hypervolemia, increased hemoglobin red blood cell count and hematocrit, decreased plasma volume, thrombocytopenia, and hypofibrinogenemia The pH is usually normal, but there is a reduction in both pCO_2 and bicarbonate On the other hand, the fixed acids particularly chlorides and proteins are increased

Atrial Septal Defects

An atrial septal defect (Fig 55) is an opening between the two atria and may be one of two types The ostium primum is an aperture low in the interatrial wall close to the ventricular septum and tricuspid and aortic valves Operative closure may interfere with conduction or cause valvular distortion An ostium secundum is an aperture high in the interatrial wall close to the base of the heart and is corrected more readily The closure of the defect decreases the volume of the pulmonary blood and increases the systemic volume

In atrial septal defect, the flow of blood from the left atrium to the right atrium constitutes a recirculation of much of the blood returned from the lungs and in addition the right atrium receives a somewhat reduced volume of blood from the systemic circulation through the inferior and superior venae cavae The right atrium becomes distended from the effect of large volumes and high pressures on its thin wall

Similarly, the right ventricle and pulmonary artery are dilated by the

high pressure transmitted from the right atrium, markedly increasing the pulmonary blood flow Over a period of time, two to four decades, the right ventricle gradually dilates and fails, mainly due to increasing pulmonary artery pressure Concomitant changes are seen in the smaller pulmonary arteries and arterioles, where intima is thickened by fibrous proliferation, greatly narrowing their lumina

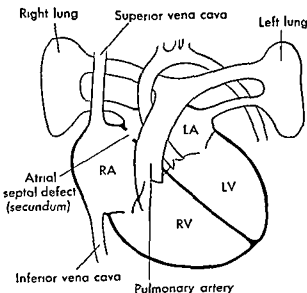


Fig 55 Atrial septal defect—diagram of ostium secundum (Reprinted by permission of the publishers and The Commonwealth Fund from Helen B Taussig *Congenital Malformations of the Heart* Cambridge Mass Harvard University Press Copyright 1947 by The Commonwealth Fund)

Cyanosis does not occur in an atrial septal defect until the pressure in the right atrium exceeds that in the left atrium and there is a right to left shunt of unoxygenated blood The heart rate is moderately increased, while blood pressure is normal or slightly low in all extremities

While hemoglobin, hematocrit, and red blood cell count are usually normal or occasionally below normal, blood volume is increased moderately

The heart is greatly enlarged and globular in the roentgenogram The right atrium right ventricle and pulmonary artery are dilated, with the oblique view particularly, showing great prominence of the right atrium The pulmonary artery branches are dilated and pulsate showing hilar dance upon fluoroscopy and the peripheral vascular lung markings are increased

By electrocardiogram right axis deviation signifying right bundle branch block is seen There are very large P waves indicative of right atrial enlargement Wide, notched QRS complexes occur

Results of cardiac catheterization are illustrated in Figure 56

Ventricular Septal Defects

Ventricular septal defects are often associated with major vascular anomalies near the heart and will be discussed under that subject Here, however, we refer to the pure forms of ventricular septal defect, which may be muscular (in the muscular part of the septum), membranous (in the membranous septal portion), or infravalvular (at the junction of heart pulmonary trunk, and aorta)

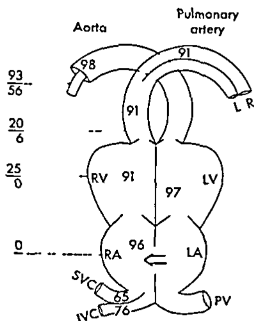


Fig 56 Atrial septal defect—diagram of cardiac catheterization Arrow indicates left to right shunt Numbers inside heart chambers indicate oxygen saturation those outside indicate blood pressures

In the severe form or large defect, oxygenated blood passes from the left ventricle to the right ventricle and is associated with pulmonary hypertension The patients may have retarded growth bouts of cardiac failure and frequent attacks of pneumonia Both ventricles become markedly enlarged pulmonary vascular markings are increased and the hilum may even show pulsations on fluoroscopy The electrocardiogram may show right ventricular preponderance Closure of the defect decreases pulmonary blood volume and increases systemic circulating volume

Results of cardiac catheterization are illustrated in Figure 57

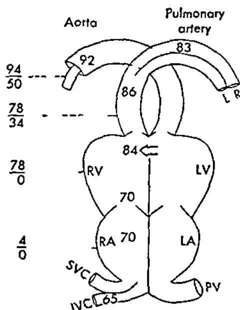


Fig 57 Ventricular septal defect—diagram of cardiac catheterization Arrow shows left to right shunt Numbers inside heart chambers indicate oxygen saturation those outside indicate blood pressures

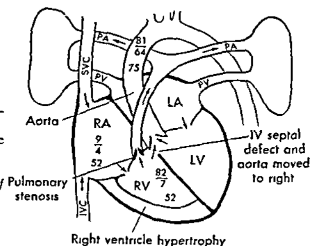


Fig 58 Tetralogy of Fallot—diagram showing abnormalities (Reprinted by permission of the publishers and The Commonwealth Fund from Helen B Taussig *Congenital Malformations of the Heart* Cambridge Mass Harvard University Press Copyright 1947 by The Commonwealth Fund)

Tetralogy of Fallot

Tetralogy of Fallot (Fig 58) consists of

1 Stenosis of the pulmonary artery or infundibulum
2 Overriding or dextroposition of the aorta
3 Membranous ventricular septal defect
4 Right ventricular hypertrophy

The blood flows from the right ventricle into the aorta or left ventricle producing a right to left shunt Therefore a small amount of blood flows

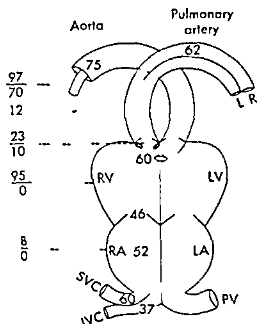


Fig 59 Tetralogy of Fallot—diagram of cardiac catheterization Numbers inside heart chambers indicate oxygen saturation those outside indicate blood pressures

through the pulmonary circulation, and a large amount of poorly oxygenated blood flows through the systemic circulation Squatting increases right heart filling essential in order to maintain cardiac output This hypoxic state causes an elevated hematocrit and hemoglobin, a lowered systolic and elevated diastolic pressure, and a rapid pulse Blood volume is increased A combination of increased blood viscosity with decreased myocardial tone tends to produce stasis of the blood and consequent cerebral accidents

One of the specific laboratory and clinical determinations which aids in the diagnosis of this condition includes the chest x-ray, presenting a typical boot shaped configuration of the cardiac shadow due to the absent pulmonary conus Right ventricular enlargement is noted with reduced vascular markings in the periphery of the lung fields The electrocardiogram shows right axis deviation, while the usual results of cardiac catheterization are as illustrated in Figure 59 Thereby confirming a right-to-left shunt angiocardiography demonstrates simultaneous right and left ventricular filling with poor filling of the pulmonary artery

Surgical treatment is designed to increase pulmonary blood flow either by a Blalock-Taussig operation wherein the subclavian artery is anastomosed to the pulmonary artery, by a Potts Smith procedure anastomosing the aorta to the pulmonary artery or by an operation in which the pulmonary obstruction is excised and the ventricular septal defect repaired

Eisenmenger's Complex

This complex is similar to a tetralogy of Fallot, but there is neither pulmonic stenosis nor right ventricular hypertrophy It is ordinarily classified with ventricular septal defects

Congenital Aortic Stenosis and Subaortic Stenosis

Aortic stenosis may be congenital or acquired The congenital variety may be valvular or subvalvular Occasionally there is a dilatation of the aorta distal to the stenosis, the so called poststenotic dilatation

The congenital type may not be diagnosed until the child is two or three years of age, at which time the left side of the heart is frequently hypertrophied Blood pressure often shows a low systolic and small pulse pressure, although if there is any degree of incompetence, systolic and diastolic pressures are both low

X-rays of the chest demonstrate left ventricular enlargement with poststenotic enlargement of the aorta showing marked pulsations on fluoroscopy Mild cases show normal ECG however, when stenosis is severe, ECG shows signs of left ventricular hypertrophy

Since the left side of the heart cannot be catheterized in this instance, cardiac catheterization shows nothing definitive Suggestive evidence is a raised pulmonary artery pressure Angiocardiogram may be performed by percutaneous puncture of the enlarged left atrium or left ventricle, demonstrating the stenotic aortic valve

Pulmonic Stenosis

Pulmonic stenosis (Fig 60) may be either valvular, or infundibular proximal to the valve The right ventricle hypertrophies and the right atrium enlarges

The flow of blood through the lungs is diminished and the blood is dammed back into the right ventricle and right atrium Such a patient does not squat because the right heart is overfilled with blood at a high pressure In addition cyanosis is rare, since there is no right to-left shunt unless there is a patent ductus arteriosus Substernal or parasternal regions may lift with the pulsations of the right ventricle As one might expect there is no hemoconcentration The heart may be normal in size or slightly enlarged, and the right ventricle is hypertrophied, but not dilated

X ray examination of the thorax discloses a normal or slightly enlarged heart with fullness of the pulmonary conus, probably due to poststenotic dilatation Further scrutiny will reveal prominent pulmonary arteries

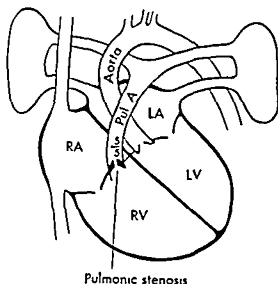


Fig 60 Pulmonary stenosis—diagram of defect (Reprinted by permission of the publishers and The Commonwealth Fund from Helen B Taussig *Congenital Malformations of the Heart* Cambridge Mass Harvard University Press Copyright 1947 by The Commonwealth Fund)

and, in addition, decreased vascularization of the peripheral lung fields

Extreme right axis deviation is exhibited by the electrocardiogram, even greater than that seen in tetralogy of Fallot, with evidence of maximal right ventricular hypertrophy

Angiocardiogram shows a narrowed stenotic valve or infundibulum between the right ventricle and the pulmonary artery Since there is no septal defect, there is no immediate filling of the left heart in a pure pulmonic stenosis However, additional important diagnostic information is gained during cardiac catheterization whereby a high right atrial pressure is revealed, accompanied by a markedly increased right ventricular pressure, with a very low pulmonary artery pressure (Fig 61)

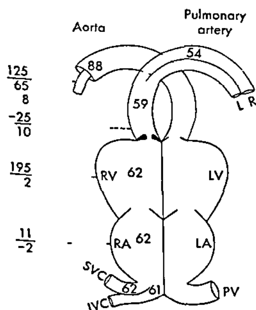


Fig 61 Pulmonary stenosis—cardiac catheterization data Numbers inside heart chambers indicate oxygen saturation those outside indicate blood pressures

Tricuspid Atresia

Tricuspid atresia is a serious congenital anomaly with marked stenosis of the tricuspid valve and shunting of blood through an atrial septal defect from right to left atrium left ventricle and systemic circulation Left ventricular hypertrophy results Pulmonary blood flow is through either the patent ductus arteriosus or ventricular septal defect, together with collateral circulation through the bronchial arteries Cyanosis is marked at an early age with engorgement of the neck veins and hepatomegaly

Radiological examination of the chest confirms the enlargement of the left ventricle and shows diminution in size of the pulmonary vessels Electrocardiograph shows left ventricular preponderance

Surgical cure is either by opening the tricuspid valve a Blalock-Taussig operation or a Potts-Smith operation The likelihood of underdevelopment of the pulmonary blood vessels makes the outcome of any of these operations problematical

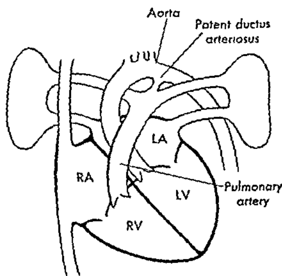


Fig 62 Patent ductus arteriosus—showing defect (Reprinted by permission of the publishers and The Commonwealth Fund from Helen B Taussig *Congenital Malformations of the Heart* Cambridge Mass Harvard University Press Copyright 1947 by The Commonwealth Fund)

Patent Ductus Arteriosus

Persistent patent ductus arteriosus (Fig 62) extends from the aorta immediately distal to the origin of the left subclavian artery, to the pulmonary artery just proximal to its bifurcation A persistent patent ductus arteriosus varies considerably in width, length, and shape

Since it propels both systemic and pulmonary blood the heart becomes moderately enlarged with hypertrophy of the left ventricle and the left

atrium As the pulmonary artery pressure rises it may in addition cause hypertrophy of the right ventricle and the pressure in the pulmonary system may exceed that in the systemic, causing reversal of the left to right shunt Hypervolemia is, naturally, a concomitant finding

Chest film in early cases reveals a normal sized heart which enlarges greatly as the disease progresses, with early enlargement of the left ventricle Because of increased blood flow in the pulmonary arteries and the high pulmonary pressure, vascular markings in the lungs are emphasized High pulmonary pressure is further verified in the fluoroscopic examination by the marked pulsation of the pulmonary arteries

Electrocardiogram often confirms left ventricular hypertrophy, and later shows right ventricular hypertrophy

Diagnosis is generally made clinically without catheterization However, with reversal of blood flow, the diagnosis may be more difficult at which time cardiac catheterization (Fig 63) is helpful in establishing the diag-

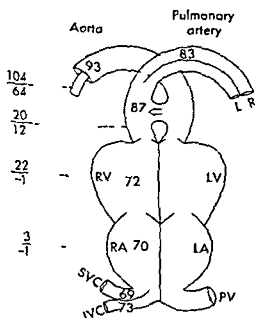


Fig 63 Patent ductus arteriosus—diagram of cardiac catheterization figures Numbers inside heart chambers indicate oxygen saturation those outside indicate blood pressures

nosis the most convincing evidence being passage of the catheter through the patent ductus The pulmonary artery oxygen content is higher than that of the right ventricle, but this is not always a conclusive finding Retrograde aortogram shows the dye passing directly from the aorta through the patent ductus into the pulmonary arteries With high pulmonary pressure demonstrated by cardiac catheterization the anesthesiologist is aware that there is considerable increase in the severity of the dis-

Tricuspid Atresia

Tricuspid atresia is a serious congenital anomaly with marked stenosis of the tricuspid valve and shunting of blood through an atrial septal defect from right to left atrium, left ventricle, and systemic circulation Left ventricular hypertrophy results Pulmonary blood flow is through either the patent ductus arteriosus or ventricular septal defect, together with collateral circulation through the bronchial arteries Cyanosis is marked at an early age with engorgement of the neck veins and hepatomegaly

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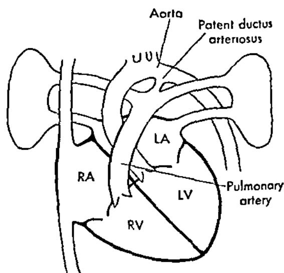


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cyanosis in the lower extremities The left ventricle increases in size and subsequently the left atrium may enlarge, with a systemic blood pressure which is considerably higher in the arms than in the legs

X rays of the chest show an enlarged left ventricle, seen as a posterior bulge in the left lateral oblique film In the anteroposterior view, rounding of the apex is noted Notching of the ribs is seen, due to increased pressure in the tortuous intercostal vessels and there is absence of any distinct aortic arch segment

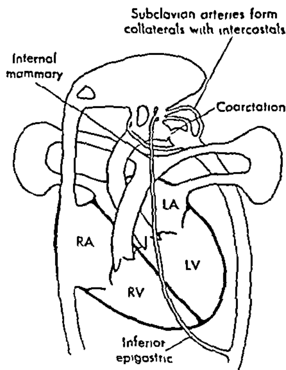


Fig 64 Coarctation of the aorta (Reprinted by permission of the publishers and The Commonwealth Fund from Helen B Taussig *Congenital Malformations of the Heart* Cambridge Mass Harvard University Press Copyright 1947 by The Commonwealth Fund)

Electrocardiogram may be normal, and evidence of left ventricular hypertrophy occurs only in a few instances However, incomplete right bundle branch block is common, and the P wave may be broad and notched

Right cardiac catheterization is of little value, for most of the complicating anomalies are on the left side of the heart, however the retrograde aortogram will show the stenosis and also the poststenotic dilatation It will also give some indication of the amount of collateral circulation The anesthesiologist is often called upon to anesthetize these infants for the retrograde aortogram

Persistent Double Aortic Arch (Vascular Ring)

Vascular ring consists of those anomalies of the aortic arch which cause symptoms of tracheal or esophageal compression or both The vascular ring may be formed by a double aortic arch, a double ductus arteriosus,

ease Although the cardiologist is not always definite about the presence of a reversal of blood flow, this fact may be confirmed later when the chest is opened and the pulmonary artery pressure can be measured The eventual course without operation may be cardiac failure or subacute bacterial endocarditis

Pulmonary aortic Window

If the truncus arteriosus does not completely divide so as to separate pulmonary artery and aorta, a small residual communication between the aorta and pulmonary artery will persist just above the valves, although the main pulmonary artery still arises from the right ventricle and the aorta from the left ventricle This aperture can be closed surgically, unlike the condition known as truncus arteriosus in which there is a common ventricle and the pulmonary artery and aorta are still one common trunk

Coarctation of the Aorta

Occurring as a localized stenosis of the aorta distal to the origin of the left subclavian artery, coarctation of the aorta may be divided into infantile and adult types In the infantile type, the upper part of the body is well supplied with oxygenated blood from the carotid and subclavian arteries The lower part of the body is supplied through the ductus arteriosus which opens into the aorta distal to the stenosis The pressure being low in the descending aorta, some of the poorly oxygenated pulmonary artery blood can pass into it However should the patent ductus close the condition may become critical, since the lower portion of the body has minimal blood flow through the stenosed aorta and collateral vessels Since the infantile type does not usually respond well to surgical correction, we shall confine our remarks mostly to the adult type

In the adult type, the stenosis is distal to the patent ductus arteriosus, and even though the early days of the infant may be precarious, in most cases it is possible to postpone operation ten or twelve years allowing for greater development of the collateral circulation through the branches of the subclavian arteries connecting with the intercostals and branches of the internal mammary joining the inferior epigastric arteries (Fig 64) Atresia of the aortic isthmus may be present necessitating resection and grafting rather than end to-end anastomosis As in all cases of stenosis, there may be poststenotic dilatation

Often these children are somewhat robust and have no limitation of activity Nor are there signs of failure until later on when the work of the left ventricle has become excessive There may be, however, some slight

in the pulmonary artery there is dilatation of both central and peripheral pulmonary vessels, with dilatation of the right ventricle often demonstrated by lateral view of the chest

The electrocardiogram displays broad or notched P waves, but cardiac catheterization is not of great value because of the presence of the shunts which tend to change their direction from time to time

Operation for this complication is a difficult technical procedure and the results at the present time are generally disappointing

Anomalous Pulmonary Venous Connection

This condition is due to persistence of a connection between the former fetal splanchnic plexus and cardinal venous system coupled with failure of the left atrium to join the pulmonary blood vessels Therefore, the pulmonary veins drain into the right atrium instead of the left This anomalous pulmonary venous connection may also represent an anomalous position of the atrial septum

ACQUIRED DISEASES OF THE HEART

In the past few years improved methods of treating acquired heart diseases have resulted in a marked reduction in the number of children with the consequent permanent sequelae Nevertheless, we consider it advisable to include a classification of acquired heart diseases since when a patient has such a disease it presents problems for the anesthesiologist

Rheumatic Fever

At one time rheumatic fever was the major cause of acquired heart disease in children, and often they were anesthetized for the removal of their tonsils, considered to be the source of the infection On occasion, also, children with rheumatic fever were mistakenly operated upon for appendicitis Today, if surgery upon an infant or child with rheumatic fever is mandatory we would suggest adequate premedication, avoidance of overdosage of anesthetic agents particularly ether and barbiturates and an adequate supply of oxygen These patients readily develop cardiac failure

Bacterial Endocarditis

With modern chemotherapy, bacterial endocarditis has become exceedingly rare However, occasionally a positive blood culture is obtained in congenital heart disease Most frequently subacute bacterial endocarditis

anomalous innominate or left common carotid arteries, or by an aberrant right subclavian artery given off by a descending left aorta and passing either between the trachea and the esophagus, or posterior to the esophagus

The vascular ring gives rise to no cardiac signs or symptoms, but as was pointed out in Chapter 4 (p 82), there can be considerable occlusion of the trachea with the patient dying in infancy from either pneumonia or hypoxia Often these patients on account of difficulty with respiration hyperextend their heads to facilitate breathing

By x-ray the barium swallow may show indentation of the esophagus or the tracheogram may demonstrate narrowing of the trachea

The anesthesiologist should keep in mind the probability of hyperdistention of the pulmonary components distal to the stenosis

Transposition of the Great Vessels

Here, the aorta arises from the right ventricle and the pulmonary artery from the left ventricle However, there may be many other associated anomalous conditions Since the superior vena cava and inferior vena cava empty into the right heart and the aorta rises from the right ventricle, the systemic system keeps recirculating venous blood With pulmonary venous drainage into the left atrium and the pulmonary artery arising from the left ventricle, there is a recirculation of oxygenated blood through the lungs In other words there is, essentially, a dissociation of the two systems However, patients with transposition of the great vessels do not necessarily die at birth, for there is often a communcation between systemic and pulmonary systems, through either a persistent patent ductus arteriosus, atrial septal defect, or ventricular septal defect

Such infants have a history of severe cyanosis at birth and if they survive any length of time, they are markedly underdeveloped and may even be unable to walk Physical examination shows a severely cyanotic infant with the cyanosis often more severe in the upper part of the body He has marked dyspnea engorged neck vessels and enlarged liver, and his heart enlarges very rapidly in the first few weeks of life Here, too, blood volume is considerably increased

On x ray, the heart is generally enlarged Often this is a right ventricular enlargement but because of the intercommunication between the two systems, there may also be left ventricular enlargement The mediastinum is narrow, since the pulmonary artery is altered in its position, lying behind the aortic arch However, because of increased flow and pressure

is an accompaniment of this disease Therefore, anesthesia may be haz ardous for some time after the acute phase of the disease During anesthesia the danger signs are fall in blood pressure, irregular slow pulse and a prolonged P-R interval

Some patients with one of the rare muscular diseases such as Friedreich s ataxia or progressive muscular dystrophy may develop myocardial disease, although part of the myocardial weakness may be due to inactivity of the patient and bears a striking resemblance to the myocardial disease seen in prolonged bedridden patients The heart of such a patient on x ray is often small and elongated, probably due to disuse atrophy

Perhaps the most important consideration is to remember that the presence of any of these causative factors may involve the myocardium Occasionally, however the anesthesiologist has no warning of the presence of myocardial disease One patient with prolonged illness from an anal atresia had cardiac arrest on two separate occasions when small increments of ether were added to provide muscle relaxation Following this experience when the patient subsequently visited the operating room he was kept in extremely light anesthesia with no myocardial effects but conditions did not facilitate the surgery On the next two sessions in the operating room, this patient s heart was monitored carefully and frequent recordings of blood pressure taken, and although four years of age, he showed a marked blood pressure fall with the intravenous injection of 20 mg of thiopental sodium (Pentothal sodium)

Diseases of the Pericardium

Pericarditis may be caused by rheumatic fever uremia, purulent infections viral diseases, rheumatoid arthritis tuberculosis neoplasms, cysts or chronic constrictive lesions Anesthesia is hazardous in these patients We shall describe the diseases in detail because of their serious and sometimes fatal prognosis

Acute Pericarditis In children it is associated with rheumatic fever and other collagen diseases septicemia and uremia although in some instances the etiology is unknown Myocarditis may be an associated finding

As soon as the pericardial sac is full the pressure mounts as more fluid is secreted with greater compression on the heart and great vessels Because of the limitation of diastolic filling cardiac output drops and the contraction of the ventricle becomes more rapid but less powerful

These patients have a low systolic pressure and high diastolic pressure

is due to *Streptococcus viridans* occurring in patients with chronic rheumatic heart disease or congenital heart disease notably patent ductus arteriosus and ventricular septal defect

An important feature of this disease is the anemia, which invariably increases the hazard of anesthesia However, no particular modification of anesthetic management is required for these patients

Myocardial Disease

Myocardial disease is not always readily detectable, for the cardinal signs of cardiac enlargement accompanied by changes in the S-T segment and T waves are not always present However, the anesthesiologist can scarcely overlook severe myocardial disease manifested by congestive heart failure In primary myocardial disease originating from excessive glycogen storage in the heart and from erythroblastosis fetalis, the patients seldom live beyond the first year of life

Subendocardial sclerosis (subendocardial fibroelastosis) may not be evident until the end of the first year of life, but its chief danger lies in the poor diastolic filling

Many of the exanthematic infections may depress the myocardium These include hepatitis measles, poliomyelitis, encephalitis pneumonia tularemia meningococcemia, infectious mononucleosis, rickettsial disease influenza mumps, and yellow fever However it is difficult to detect the degree of myocardial involvement unless there are changes in the electrocardiograph

There are several inflammatory diseases of the heart other than those caused by the exanthemata, which may be characterized by a sudden onset of left and right heart failure with dyspnea cyanosis pallor, hacking cough gallop rhythm and a low-voltage ECG tracing These patients present a serious anesthetic problem and should be given minimal amounts of premedication and anesthetic agent Ether and intravenous barbiturates because of their tendency to produce depression of the myocardium are exceedingly hazardous unless used with extreme caution

Diphtheria deserves special mention because of the effect of the exotoxin upon the heart Patients with this disease may develop atrioventricular block and severe shock and sudden death is not infrequent Distant heart sounds or gallop rhythm are ominous signs One of the authors has seen a patient with diphtheria die suddenly on the operating table Hyaline degeneration of the cardiac muscle which may take weeks to regenerate

anesthesiologist should be alert for signs of overdosage with digitalis, notably an irritable myocardium wherein the irritability is increased by vasopressors, calcium preparations, epinephrine, or cyclopropane

Endocrine Diseases

Thyroid Two abnormal thyroid conditions, hyperthyroidism and hypothyroidism, affect the heart

Hyperthyroidism does occur rarely in children, but seldom before the age of twelve years These patients have myocardial stimulation, producing tachycardia and increasing cardiac output, although the heart is seldom enlarged in this age group The systolic blood pressure is elevated Like many patients with a stimulation of their heart, the electrocardiogram shows the typical elevation of P and T waves with a shortening of the P-R interval

Hypothyroidism may be either congenital (cretinism) or acquired (juvenile hypothyroidism) These children are mentally sluggish and have the characteristic physical features of this disease, exhibiting bradycardia and decreased blood pressure The heart is grossly enlarged from dilatation, and microscopic sections demonstrate fatty infiltration In many instances the disease is complicated by an anemia which may be partially responsible for these cardiac effects The electrocardiogram shows small P and T waves, but the QRS may be normal

Parathyroids Hyperparathyroidism is usually due to overdevelopment of the glands or to chronic renal disease, such as glomerulonephritis or pyelonephritis There is a bradycardia with shortening of the Q-T interval due to hypercalcemia The anesthesiologist should keep in mind the possibility of increased cardiac irritability from *hypercalcemia* when selecting his anesthetic agents

Hypoparathyroidism presents the opposite picture, including hypocalcemia, with resulting tachycardia and lengthening of the Q-T interval in the electrocardiogram The anesthesiologist should be aware that there is a decreased quantity of that excellent cardiac stimulant, calcium Its restoration by the use of calcium gluconate is advisable before anesthesia since such patients can readily show myocardial depression with certain anesthetic agents

Pancreas In most instances the diabetic is well under control when presented for elective surgery The potassium level of the blood is usually close to normal, and he has been given adequate insulin and glucose However it may be necessary upon occasion to anesthetize a diabetic

with a low pulse pressure Unlike the normal patient their systolic blood pressure drops during inspiration (pulsus paradoxus), with markedly distended and nonpulsating neck veins

X-ray reveals a large heart shadow, while the electrocardiogram shows marked decrease in amplitude of all waves

If it is necessary to anesthetize such patients, it is important to withdraw as much pericardial fluid as possible before anesthesia

Chronic Adhesive Pericarditis In this disease an entirely different picture is seen, usually developing after many attacks of acute rheumatic fever The heart becomes enormously hypertrophied as the pericardial adhesions restrain effective systolic contraction The heart continues to hypertrophy and may even deform the anterior thorax, while the cardiac reserve becomes increasingly diminished These patients may be presented for corrective surgery

Electrocardiogram reveals tachycardia low amplitude QRS and T waves and abnormal shape of the S-T segment X-ray may show an enlarged heart and congested pulmonary vessels

Chronic Constrictive Pericarditis In this disease there are no adhesions between the two layers of the pericardium but the pericardium itself becomes thickened and fibrous, often calcified It is generally due to tuberculosis This variety of pericarditis presents obstruction similar to the acute type, since there is limitation of diastole There is no cardiac enlargement but as in adhesive pericarditis, it may be complicated by gross portal congestion and is therefore, often accompanied by ascites

Operative correction consists of resection of part of the thickened pericardium to allow free cardiac expansion

In both types the disease must be quiescent before operation, as shown by normal temperature, normal sedimentation rate and correction of any anemia Insofar as possible the patient s general health must be well established

Congestive Heart Failure

Although congestive heart failure is more commonly seen in chronic cardiac or respiratory disease it also occurs frequently in acquired diseases of the heart One of the most important early signs in children is hepatomegaly accompanied by weak heart sounds rapid pulse cardiac enlargement and in older children, pulmonary or generalized edema There may also be pallor or cyanosis and distention of the veins in the neck These patients are often treated with digitalis preparations and the

Vitamin Diseases

Vitamin B deficiency (beriberi) may cause right heart failure with tachycardia, enlargement of the liver, edema, and all the signs of congestive heart failure, while deficiency of vitamin C (scurvy) occasionally causes cardiac enlargement from the resulting anemia In vitamin D deficiency (rickets), the only effect on the heart is by direct cardiac compression from the rachitic chest deformity, but vitamin D excess produces hypercalcemia with the same cardiovascular effects as hyperparathyroidism, causing increased irritability of the myocardium

Anemia

Acute hemorrhage results in tachycardia low blood pressure, and dehydration, the well-known picture of shock, however, patients with chronic anemia usually have only a moderately low blood pressure and a moderate increase in the heart rate The electrocardiogram shows a definite decrease in voltage, with all complexes reduced Such patients with their reduced myocardial contractility, reduced blood volume, and chronic hypoxia readily develop shock during induction or maintenance of anesthesia Correction of the anemia can be attempted with blood transfusion, but these patients require careful and slow transfusion since their circulation readily becomes overloaded A high venous pressure warns that cardiac failure may be imminent

Renal Diseases and Idiopathic Hypertensive Cardiovascular Disease

Some chronic nephritics later in the course of the disease develop hypertension which generally accompanies the retention of urea and other nitrogenous products of metabolism Occasionally however, a child will develop a hypertension similar to essential hypertension as seen in the adult and no cause can be discovered Any drug or technic which might cause a precipitous drop in blood pressure should be avoided It should also be remembered that a child with essential hypertension can die without warning

Trauma

Apart from the acute anemia caused by hemorrhage trauma can produce many additional cardiovascular effects Any penetrating wound of the heart may produce cardiac tamponade or the myocardium may be

child with infection whose diabetes cannot be controlled before the in fection is eliminated By the time most of these patients arrive for anes thesia, they are in acidosis and hypokalemia, with an extremely rapid heart rate If the duration of the surgery is beyond a few minutes, the heart should be monitored with continuous electrocardiogram Low T waves and prolonged Q-T interval suggest a potassium deficiency which should be rectified The fluid and electrolyte balance of this type of pa tient requires the skill of an expert

A severe juvenile diabetic may have complications such as atheroscler osis and degenerative changes in the glomeruli with resulting hypertension

Pituitary There are a large number of pituitary diseases affecting the cardiovascular system among them being Cushing s syndrome, which is due to a basophil tumor of the pituitary It is rare in children but results in hypertension when it occurs Gigantism may produce cardiac dilatation and hypotension Simmond's disease, often associated with hypothyroid ism, results in low blood pressure and slow pulse

Adrenals Addison's disease may occur as a result of congenital ab sence of the adrenal cortex, from destruction of the adrenal cortex, or from inadequate secretion of adrenocorticotropin These patients have a small heart hypotension, and increased serum potassium Preparation in most cases of this nature consists of the administration of hydrocortisone norepinephrine, whole blood, and intravenous fluids containing saline

Hyperadrenocorticism is caused either by therapy with corticotropin or by an adrenal cortical tumor It causes the same cardiac effects as a baso phil adenoma of the pituitary gland These patients have hypertension and a lowered serum potassium

Pheochromocytoma is usually a tumor of the adrenal medulla but can be located in any of the sympathetic ganglia These patients have cardiac enlargement rapid pulse and hypertension The excess production of norepinephrine and epinephrine may be a hazard since it stimulates and in creases the irritability of the myocardium

Surgical removal is the treatment but the actual procedure is dangerous, for manipulation of the gland may flood the circulation with excess nor-epinephrine and epinephrine The anesthesiologist however should be prepared for the noticeable decrease in norepinephrine and epinephrine with resulting hypotension following the removal of the gland and should be ready to administer continuous norepinephrine intravenous drip at this time

Disorders of Rate and Rhythm

We have often employed the electrocardiograph as a monitor of the cardiovascular system It may provide early detection of untoward effects of anesthetic agents and related intravenous drugs, as well as giving early warning of hypoxia We now make it a practice to use the electrocardiograph to monitor the cardiovascular system in the more difficult cases such as congenital heart disease

Paroxysmal atrial flutter can occur at times in the premature This may be accompanied by shallow respiration and cyanosis, but the infant generally recovers from the flutter in the first few months of life

Premature beats are common in the infant in the first three months of life, and paroxysmal tachycardia in infants and children is comparatively common Occasionally, however, it may be accompanied by restlessness, increased respiration, pallor, and cyanosis Ultimately, emesis, cardiac enlargement, and even failure may occur if not treated The usual treatment is digitalization

During anesthesia the anesthesiologist should be aware of any sudden change in cardiac rate A bradycardia (Fig 65) may indicate acute hy-



Fig 65 Electrocardiogram *(Left)* Normal rhythm *(right)* bradycardia in acute hypoxia and overdose of anesthetic agent

poxia or overdosage of anesthetic agent A severe acute hypoxia may show bradycardia, low take-off of the S T segment, and widening of the QRS complex (Fig 66) An apical rate greater than 200 per minute usually indicates a ventricular tachycardia, and may be due to overdosage of anesthetic agent or hypoxia Immediate detection of the cause and cor-



Fig 66 Electrocardiogram showing left to right moderate hypoxia to severe hypoxia

bruised by a crushing injury to the chest Valvular rupture, particularly of the aortic or mitral valve, has been known to occur and is invariably fatal in a short period of time

The most frequent cardiac arrhythmia following injury is atrial flutter or fibrillation, although paroxysmal tachycardia, heart block, and extrasystoles may also occur

If it becomes necessary to anesthetize a child who has recently had a traumatic injury, especially a blow or crushing injury to the chest, the anesthesiologist must remember that the danger of myocardial damage may be serious, and should proceed cautiously

Endocardial Fibroelastosis

Occurring frequently with any congenital cardiac defect, this condition has also been found in an apparently normal infant one month of age Cardiomegaly and cardiac failure occur, with the electrocardiogram showing left ventricular hypertrophy The prognosis is very serious, and death usually occurs before two years of age Many attempts have been made to correct these surgically, with little satisfaction, the latest being poudrage to increase myocardial circulation

Neurocirculatory Asthenia (Reduced Cardiac Reserve)

There are several cardiac conditions in this classification In infants they contribute many of the cases of cardiac arrest, but very little is known about specific cardiac damage, except that it appears to occur in any patient with insufficient cardiac reserve

Such hearts are often small but there are no other special characteristics The anesthesiologist should read the history of the patient carefully Any patient convalescing from an acute illness any patient with a chronic infection or with malnutrition or any patient who has been in bed for a long time apparently develops a small heart with little or no reserve Hypoxia or slight overdosage of anesthetic agents readily causes arrest of these hearts and it is advisable to employ a cardiovascular monitor throughout induction and maintenance of the anesthesia Any bradycardia or diminution of precordial heart sounds will require instant action on the part of the anesthesiologist Immediate ventilation of the lungs with a high percentage of oxygen, removal of the anesthetic agent, and intravenous calcium gluconate administration are essential As well no anesthetic agent should be selected which would further depress the myocardium, for example, ether, halothane (Fluothane) (2-bromo 2 chloro-1 1 1 trifluoroethane), and large dosages of barbiturates

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rection are imperative for ventricular tachycardia often precedes ventricular fibrillation A tachycardia below 200 usually suggests a sinus tachycardia The electrocardiogram is now a recognized diagnostic safety aid for the anesthesiologist even though he perhaps is not qualified to make the finer diagnostic distinctions

Cardiac arrhythmias due to cardiovascular disease may be present preoperatively, arrhythmias from other causes may occur during anesthesia or postoperatively A brief classification follows, proceeding from the more innocuous arrhythmias to the serious ones

Arrhythmias with Sinus Pacemaker

1 Sinus tachycardia
2 Sinus bradycardia
3 Sinus arrhythmia

Arrhythmias with Ectopic Pacemaker

1 Ectopic beats
2 Ectopic tachycardia
   (a) simple paroxysmal tachycardia
   (b) ectopic atrial tachycardia
   (c) paroxysmal atrial tachycardia with block
   (d) atrial flutter
   (e) atrial fibrillation
   (f) ventricular flutter and fibrillation

Arrhythmias Caused by Conduction Defects

1 Sinoatrial block
2 Atrioventricular block
   first—with long P R interval
   second—occasionally P not conducted to ventricle
   third—complete dissociation of atria and ventricles
3 Cardiac arrest

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CHAPTER 6

EVALUATION OF THE HEMIC AND LYMPHATIC SYSTEMS

HEMIC SYSTEM

Prior to anesthesia, every patient should receive a complete blood examination, including hemoglobin, red and white blood cell counts, differential cell count bleeding time, and clotting time With this preliminary, and certainly minimal, study completed, the hemic system must be evaluated further in terms of the blood and the blood-forming organs

BLOOD

The Erythrocyte

Hemoglobin Since the most important constituent of the erythrocyte from the standpoint of anesthesia is the hemoglobin the variations in the oxygen dissociation curve must be considered carefully

If the oxygen dissociation curve of the animal fetus, as outlined by Barcroft can be assumed to be analagous to that of the human, then it must be noted that the human fetal curve is shifted further to the left than it is in the adult, thus favoring increased oxygen saturation of the hemoglobin at low oxygen tensions—a most favorable situation for the placental transfer of oxygen from mother to infant With the approach of birth this curve moves rapidly to the right however during the first sixteen weeks of life and even longer in the premature, the curve may still be to the left of that of the adult This position of the oxygen dissociation

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careful metering of anesthetic agents to avoid atonia of their hypotonic muscles and depression of their cardiovascular systems, adequate oxygen and pulmonary ventilation, for increasing cyanosis from hypoxia is not detectable readily, early and adequate blood replacement for surgical blood loss, since they go into shock readily Furthermore, a hemoglobin determination must be done within a few days before surgery, for infants and children can develop severe anemia far more rapidly than adults

Physiological Anemia The mother stores iron during her last trimester and transfers an adequate supply to the fetus so that the normal full-term newborn has a hemoglobin around 20 gm per 100 ml of blood (Fig 67) From this period on there is a gradual decrease in the hemoglobin of the neonate

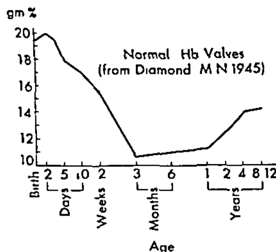


Fig 67 Diagram of normal hemoglobin values from birth to twelve years (Reprinted by permission of the publishers and The Commonwealth Fund from K D Blackfan and L K Diamond *Atlas of the Blood in Children* Cambridge Mass Harvard University Press Copyright 1944 by The Commonwealth Fund)

Accompanying the red cell destruction of physiological anemia there will be an elevation of serum bilirubin A positive van den Bergh test (hyperbilirubinemia), usually evidenced by jaundice or so called icterus neonatorum is present in 50 per cent of infants from the first to fifth day of life, but is more severe and prolonged in the premature The released bilirubin is removed from the blood by the liver but the immaturity of the liver in the newborn retards the removal Infants with severe jaundice tend to have temperature instability lassitude and anorexia and therefore demand careful anesthetic management In particular sedatives should be omitted in the premedication

Little can be done to prevent the normal physiological anemia of the first three months of life However if from birth the infant is treated with iron anemia may be avoided from the third month onward

curve certainly favors uptake of oxygen in the hemoglobin of the neonate

The Normal Erythrocyte Picture The full term infant has a red blood cell count of around 6,000 000 to 7 000,000 per cu mm, accounting largely for a specific gravity of 1 060 to 1 085 of the blood Fifteen per cent of these red blood cells are nucleated, but this percentage begins to drop by the end of the third day and by the end of the first week has reached 1 per cent

The total red blood cell count decreases rapidly from birth to the third month of life, at which time it averages about 4,000,000 per cu mm rising gradually to about 4 500,000 per cu mm at the end of the third year, the specific gravity of the blood at this time is 1 048 to 1 050 As a concomitant finding the hematocrit at birth is approximately 52 per cent and it also falls somewhat rapidly during the first three months of life to the region of 45 per cent

The mean diameter of the red blood cell at birth is 8 6 μ Throughout the first year of life the macrocytes are replaced by smaller red blood cells so that at the end of the third month the mean diameter of the red blood cell is about 7 7 μ As the smaller red blood cells increase in number, the mean diameter of the red blood cell decreases to 7 3 μ by the end of the first year

The mean corpuscular volume is 110 cubic microns at birth and decreases to 90 cubic microns by the third month, at which level it should remain throughout life

Variations and Abnormalities of the Erythrocyte

Erythrocytosis In some instances there is a marked increase in the red blood cell count often accompanying chronic hypoxia from pulmonary disease or from heart disease The most important point for the anesthesiologist to bear in mind if there is markedly elevated red blood cell count is that thrombosis can readily occur, for the viscosity of the blood is increased by the increased cellular elements Ether, except in very low concentrations, dehydration or depression of circulation must be avoided in such patients

Anemia Far more common than a polycythemia is anemia affording a constant threat to the life of the patient since the lowered oxygen carrying capacity of the blood enhances the risk of surgery and anesthesia The anesthesiologist should keep in mind that anemic patients require lighter sedative premedication, for they depress very easily cautious induction, for their ease of induction may result in overdosage of anesthetic agent,

be abdominal pain, jaundice, and weakness A splenectomy, indicated in any patient with this disease, will produce a remission of the hemolysis and the anemia

On the other hand, in acquired hemolytic anemia, the patient may not actually show anemia unless there has been bleeding, but if there has been bleeding the patient will have an extremely low hemoglobin

In congestive splenomegaly (Banti s syndrome) thrombocytopenia is the predominant characteristic The presence of moderate anemia, leukopenia, and esophageal or gastric varices are other symptoms of this disease The surgical treatment is either a splenectomy or a portocaval shunt to improve the collateral circulation If there is a history of episodes of hematemesis the passage of a large traumatizing stomach tube might rupture the varices and cause a severe hemorrhage

In the severe form of Mediterranean anemia (thalassemia or Cooley's anemia) there is hypochromic microcytic anemia commencing in the first year of life, and sometimes is accompanied by slight jaundice There may be considerable enlargement of the liver and spleen The blood picture shows anisocytosis poikilocytosis, basophilic stippling, decreased fragility of the red cells, reticulocytosis, and some nucleated erythrocytes X-ray of the bones shows a thinning of the cortex and a widening of the medulla due to marrow hyperplasia A splenectomy is done usually to relieve the discomfort produced by the very large spleen The anemia in these patients must be treated with transfusions before surgery

In thrombocytopenic purpura, generally developing before the age of six years, there is often a severe anemia, most frequently caused by bleeding from the skin, nose, gums, and urinary tract, and occasionally by bleeding into the central nervous system Petechiae splenomegaly, and fever may be present in patients with this disease The characteristic blood picture shows thrombocytopenia delayed clot retraction, and prolonged bleeding time If conservative medical treatment does not cure the disease, as it does in most patients a splenectomy is indicated Splenectomy is followed by reduced bleeding time and a return to normal of the platelet count

The Normal Leucocyte Picture

The white blood cell count drops from an average of 20 000 at birth to 10 000 in the third month of life at which level it remains throughout the first year It further decreases to about 8000 at the fifth year and maintains this level throughout childhood

At birth the polymorphonuclear leucocytes predominate being about

Pathological Anemia The diagnosis and treatment of a pathological anemia falls primarily within the province of the hematologist Nevertheless, a useful guide to the anesthesiologist is found in Diamond s tabulation of the pathological anemias, wherein it is noted that 61 per cent of the anemias of infancy and childhood are secondary to infection while 27 per cent are secondary to dietary or blood absorption defects The remainder a relatively small percentage, is comprised of those associated with prematurity or heredity and those secondary to blood loss toxins, or such diseases as leukemia, aplastic anemia congestive splenomegaly, etc It would be beyond the scope of this book to attempt a discussion of the causes and effects of all of the anemias in detail, however, a few are deserving of special mention to the anesthesiologist

Prematurity may influence the blood picture profoundly in that the hemoglobin may drop to 8 or 9 gm during the first three months of life, with a corresponding drop of the red blood cell count to about 3,000,000 Although compatible with life and normal activity, it must be stressed that such blood does not have the normal oxygen carrying capacity, and that such an infant will develop hypoxia much more readily

Erythroblastosis fetalis may occur in the offspring of an Rh positive male and an Rh negative female, or in the infant of an Rh-negative mother previously transfused with Rh positive blood Therefore, in order to avoid future possible difficulties, an Rh negative infant or child should not be transfused with Rh-positive blood The diagnosis of erythroblastosis fetalis is made ordinarily on the basis of progressive anemia jaundice, and marked edema It is confirmed by the laboratory tests of an Rh negative mother and an Rh positive infant The mother s blood in these cases also has a high anti-Rh titer and the infant s blood shows a positive Coomb s test

Sickle-cell anemia occurring almost exclusively in Negroes is characterized by the sickle-shaped erythrocytes, an abnormal type of hemoglobin and usually has its onset during the first decade of life Any severe insult especially hypoxia, may initiate a sickling crisis which may subsequently prove fatal

There are five pathological anemic diseases which are treated surgically by splenectomy and therefore are of specific interest to the anesthesiologist congenital hemolytic anemia, acquired hemolytic anemia, congestive splenomegaly Mediterranean anemia and thrombocytopenic purpura

In congenital hemolytic anemia there are mild anemia, spherocytosis, reticulocytosis, nucleated erythrocytes and increased osmotic fragility Urine and feces are dark and contain increased amounts of urobilinogen These infants may have periodic hemolytic crises at which times there may

Heparin

Hyperheparinemia may be caused by irradiation acute leukemia, or malignant bone disease Blood loss must be accurately replaced during surgery and postoperatively if the patient continues to bleed

BLOOD FORMING ORGANS

Spleen

There are very few diseases involving the spleen which do not at the same time involve other parts of the body Chronic infections may cause amyloidosis of the spleen but will generally involve the liver Apart from any general systemic effect which diseases of the spleen may produce, the other problem concerns the size of the spleen and its adhesions Consideration of this problem should influence the anesthesiologist in his choice of anesthetic agent and technic since on occasion the spleen is adherent to the left leaf of the diaphragm and during the removal of the spleen a pneumothorax may occur, therefore, endotracheal technic, affording positive control of the respiration is advisable

Bone Marrow

One of the important and relatively frequently seen diseases in children, especially under the age of five years is leukemia Although of many varieties, all forms of leukemia at one stage or another affect the bone marrow resulting in the gradual replacement of normal marrow substance by leukemoid cellular structure The surgery attempted on these patients is seldom major the greater portion being confined to biopsies However great care must be exercised in the choice and conduct of anesthesia, for these patients are often quite debilitated with fever anemia, low blood volume and hemorrhagic tendencies

LYMPHATIC SYSTEM

Lymphangioma or hygroma involving the base of the neck is common in infants and children It sometimes involves extensive dissection into the thorax with severe blood loss and possible production of a pneumo thorax

Chylothorax, caused by the severing of the thoracic duct during previous surgery is another complication which may confront the pediatric anesthesiologist From an anesthetic point of view, it presents difficulty in

55 per cent of the white blood cells, but the proportion drops to about 30 per cent in the third month A gradual increase in proportion occurs to the twelfth year, when the count again reaches the same level as at birth The eosinophil count, elevated on the first day drops to adult level by the second week Lymphocytes and monocytes, on the other hand, are only about 30 per cent of the white blood cells at birth, increase to about 60 per cent in the third month, and then decrease to the twelfth year The monocytes drop from a high level of 10 per cent on the first two days to the adult level of 0 7 per cent at the end of the first month

Platelets

The platelet count at birth is about 350 000 and declines to about 250,-000 by the third month maintaining that count throughout life

Blood Proteins

Albumin and Globulin The newborn and more particularly the premature has hypoproteinemia in comparison with older children According to Rapoport, in the newborn the albumin is 3 76 gm per cent and the globulin is 1 34 gm per cent, whereas in the older child the albumin is 4 70 gm per cent and the globulin is 2 03 gm per cent These figures seem to indicate that in the newborn the globulin deficiency is more marked

Fibrinogen On the rare occasion one has a patient who fails to form fibrinogen and if this patient is not given infusions of fibrinogen prior to surgery, he may bleed to death

Prothrombin

The prothrombin level in infants is half that of the adult During the first three days of life the prothrombin time is lengthened probably accounting in part for the deaths which occur in this period from hemorrhage into the lungs or skull After the first three days the prothrombin time shortens However usually such hypoprothrombinemia can be avoided if the mother or the infant is treated with vitamin K

Thromboplastinogen

Infants with a low thromboplastinogen also have a prolonged clotting time The hemophiliacs fall into this category but only 50 per cent of the hemophiliacs show a prolonged clotting time during the first month of life

CHAPTER 7

EVALUATION OF THE DIGESTIVE SYSTEM

NORMAL ANATOMY AND PHYSIOLOGY OF THE DIGESTIVE SYSTEM OF THE INFANT

The digestive system of the newborn is proportionately longer than that of the child Well-developed glands are seen in the mucosa The muscular layers of the stomach and duodenum are poorly developed but lower in the colon they show good development

During the first twenty-four hours following birth the bowel rids itself of meconium Following this, it is prepared to handle a relatively large amount of milk but even within an hour of birth a gas bubble in the stomach can be detected by roentgenological examination Infants, therefore, are able to swallow at birth and in addition, have peristaltic movement although such movement appears soon after a meal and is most active for the first two hours following ingestion

Of particular interest to the pediatric anesthesiologist is the fact that the stomach at birth empties more slowly than during any other period of life In an investigation of a group of infants one week to six months old it was found that 30 per cent emptied their stomachs in five hours or less 27 per cent from five to eight hours, and 43 per cent required more than eight hours The premature was slightly more rapid and a greater percentage had empty stomachs in less than five hours

In most instances once food has left the stomach it passes much more rapidly through the rest of the intestine especially the colon Food ingested by the newborn may appear in the stool in little more than eight

that chyle may encroach on the lung tissue, resulting in a condition similar to a pneumothorax

Lymphosarcoma, Hodgkin's disease, and other diseases originating in the lymphoid tissue may produce severe anemia, high fever, and general debility In addition pleural effusion and partial destruction of various body organs may be present in later stages of these illnesses, therefore careful evaluation of the functional capacity of the patient is essential before proceeding with any anesthesia

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portion budding later branching to form the bronchi and the lungs, while the posterior develops into the esophagus At this time, faulty development gives rise to tracheoesophageal fistula, stenosis, or atresia

The commonest congenital anomaly of the esophagus is a tracheoesophageal fistula

Tracheoesophageal Fistula

Type I (Fig 68) The type most frequently encountered is a blind upper esophageal pouch combined with a fistulous tract extending from

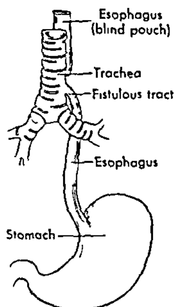


Fig 68 Diagram of tracheoesophageal fistula Type I showing blind upper pouch with fistula from trachea to lower esophagus

the posterior trachea to the lower esophagus, emptying into the stomach The diagnosis is usually established by x-ray, demonstrating the following conditions

1 A soft rubber catheter passed down through the esophagus curves acutely when it reaches the bottom of the pouch (Fig 69)

2 Air soon finds its way readily into the stomach and intestine through the fistulous opening in the trachea

3 A patch of pneumonitis in the upper lobe of the right lung suggests that the fistulous opening is close to the eparterial bronchus

Three points of particular interest to the anesthesiologist are

1 Ingested food may spill over from the blind esophageal pouch and be aspirated into the trachea The newborn has very little defense for the gag reflex is so poorly developed at this age

2 Gastric contents may be regurgitated up from the stomach through the fistula into the trachea thus causing a pneumonitis usually in the upper right lobe

hours, whereas food ingested by the adult does not appear in the stool until twenty four hours after eating

For the first few hours of life the contents of the digestive tract are sterile The stomach secretes hydrochloric acid pepsin, and rennin and the pancreas secretes lipase and trypsin The efficiency of liver function has been very difficult to estimate, but it is believed that it shows some immaturity, deduced from the fact that it demonstrates an inability to keep pace with the removal of bilirubin from the blood which has been derived from hemolysis during the first few days of life

In summary, the stomach of the infant may be distended with air within a few hours of birth, and once feeding is commenced, it is difficult to tell when the stomach has emptied, for peristalsis is so indefinite At all times the anesthesiologist should be prepared to cope with regurgitation of vomitus in the infant

CONGENITAL DISEASES OF THE DIGESTIVE SYSTEM

Since they require surgical correction early in life most of the anomalies of the digestive tract are familiar to the pediatric anesthesiologist Some surgeons treat these anomalies as emergencies, others believe it is advantageous to wait until the end of the first week when the infant has become better adapted to his environment

Cleft Lip and Palate

If one or both maxillary processes fail to fuse to the frontonasal process, facial fissures or unilateral or bilateral cleft lip or palate may occur This is apparently a hereditary condition, we have seen the lesion in three generations of the same family

Rarely are cleft lip and palate associated with other abnormalities of the body but on occasion we have seen the lesion combined with a micrognathia—a small lower jaw—and glossoptosis (Pierre Robin syndrome), and twice we have anesthetized children who had cleft lip and palate and cyanotic congenital heart disease

Patients with cleft lip and palate are very difficult to manage because first the operation is generally done when the patient is very young and secondly the malformation makes intubation difficult, but if the patient is not intubated there is a constant threat to the airway

Congenital Malformations of the Esophagus

About the fourth week of embryonic life the foregut divides into the anterior and posterior portions The anterior becomes the trachea this

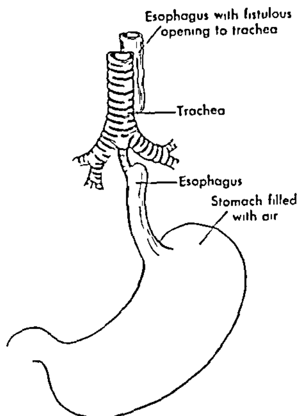


Fig 70 Diagram of tracheo esophageal fistula Type 2 showing fistula from upper esophagus to trachea and fistula from lower esophagus to trachea

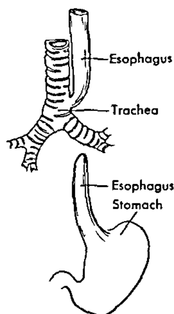


Fig 71 Diagram of tracheoesophageal fistula Type 3 showing fistula from upper esophagus to trachea and blind lower esophageal pouch

of course there are no gas bubbles in the intestine on roentgenological examination and gentle ventilation of the lungs is permissible during anesthesia, for there is no danger of overdistention of the stomach

Thirty per cent of children with tracheoesophageal fistula have asso-



Fig 69 X ray of tracheoesophageal fistula Type 1 showing soft catheter in blind upper esophageal pouch gas in the stomach and right upper lobe atelectasis

3 Positive pressure applied to the pulmonary system may readily result in gastric dilatation frequently the source of serious pulmonary embarrassment

Type II (Fig 70) A second type of tracheoesophageal fistula consists of a fistulous tract running from the upper portion of the esophagus to the trachea and a second fistulous tract running from the lower portion of the trachea to the esophagus thereupon emptying into the stomach From the point of view of anesthesia this type is very similar to the first type

Type III (Fig 71) In a third type of tracheoesophageal fistula a fistulous tract extends from the upper part of the esophagus to the trachea, but the lower end of the esophagus ends in a blind pouch In these cases,

Meckel's Diverticulum

This is a remnant of the vitelline duct running from the ileum to the umbilicus As a rule this condition is not diagnosed until later in life when it may become infected and resemble acute appendicitis, may develop a peptic ulcer or it may be recognized from intestinal hemorrhage Anemia should be corrected before surgery with blood transfusion

Imperforate Anus

In this instance the rectal pouch ends blindly at varying distances above the anus, which is imperforated Fistulae from the rectum to the lower genitourinary system and other congenital anomalies are not uncommon Of particular concern to the anesthesiologist is an associated congenital heart disease, esophageal atresia omphalocele, or atresia of the intestine The surgical repair of these additional intestinal anomalies greatly prolongs the operative time

Megacolon (Hirschsprung's Disease)

This is a congenital disease due to the absence of ganglion cells in the myenteric plexus of the rectosigmoid portion of the descending colon As a consequence there is a marked dilatation of the descending colon and severe abdominal distention In infants a colostomy is performed in the ganglionic area just distal to the aganglionic part of the bowel, and later in life when the infant is over 11 4 kg the aganglionic part of the bowel is resected Dehydration of these patients is a serious threat at all times

Celiac Syndrome and Meconium Ileus

Celiac syndrome includes several diseases such as celiac disease, congenital fibrocystic disease starch intolerance and infantile steatorrhea Children with celiac syndrome are pale undernourished have marked abdominal distention and may have a chronic cough

Of the celiac diseases the anesthesiologist most frequently encounters congenital fibrocystic disease or mucoviscidosis in which there is an excess of mucoprotein in the pancreas lungs liver sweat glands salivary glands and digestive system The disease is caused by an insufficiency of the pancreatic enzyme trypsin which normally digests the viscid mucoprotein Since a large number of these infants improve and may recover

ciated anomalies, the most common of which is congenital heart disease The anesthesiologist must keep this fact in mind for it may interfere considerably with the management of the anesthesia and the prognosis of the patient

Congenital Hypertrophic Pyloric Stenosis

This condition is characterized by reduction in the lumen of the pylorus due to hypertrophy of the inner circular muscular layer, and usually becomes an acute problem when the infant is about two or three weeks of age Of chief concern to the anesthesiologist is the high intestinal obstruction resulting in vomiting, malnutrition dehydration and metabolic alkalosis, *all of which must be corrected before surgery Gastric suction should* be instituted to prevent the aspiration of vomitus

Congenital Atresia or Stenosis of the Intestine and Colon

With arrested development of the intestinal tract during the first trimester, an atresia with complete block or stenosis with partial block may occur If the obstruction is in the duodenum, the problem is essentially the same as pyloric stenosis and the subsequent vomiting produces metabolic alkalosis Gastric suction should be instituted to decrease the possibility of aspiration in these cases

If atresia or stenosis occurs in the lower intestinal tract another difficulty may face the anesthesiologist should there be increased abdominal distention and pressure Increased venous pressure elevation of the diaphragm and decreased pulmonary volume may be the result Sudden reduction of the intra abdominal pressure from incision of the peritoneum pools the venous blood in the abdomen lowers venous pressure, decreases right heart filling and reduces cardiac output Sudden pallor will occur and the intestine may have to be packed back into the abdomen to restore the cardiac output

Malrotation of the Intestine and Colon

This condition is due to incomplete rotation of the cecum resulting in a volvulus with obstruction to the third part of the duodenum Striking abdominal distention may occur in utero in these patients Anesthetic problems are similar to those of congenital atresia or stenosis of the intestine

If general peritonitis is present a far more serious condition exists on account of the severe dehydration metabolic acidosis, rapid pulse rate, and high temperature Correction of the dehydration acidosis and especially, lowering of the body temperature make these patients a safer anesthetic risk

Intussusception

In intussusception, part of the ileum or cecum is telescoped into the contiguous colon It is generally a progressive disease which becomes very serious during the first twenty-four hours The majority of patients are under one year of age usually well nourished, and in good physical condition

Intussusception usually presents signs of intestinal obstruction with vomiting and as the disease progresses dehydration and shock may occur In fact if untreated, the patient may rapidly become moribund At times a considerable amount of blood is lost through the rectum Dehydration, acidosis, and anemia are usually partially corrected by the surgeon before anesthesia

Polyps of the Digestive Tract

Polyps of the digestive tract are often in the rectum However they do not present an anesthetic risk unless the blood loss has been severe enough to cause an anemia If there is anemia, a blood transfusion before surgery is necessary

Peptic Ulcer

Peptic ulcer can occur in young infants and is not recognized as a rule until a perforation or hemorrhage occurs Children, on the other hand give very similar clinical signs and symptoms to those of the adult, and if the ulcer has been present for some time malnutrition, intestinal obstruction, and anemia from hemorrhage may occur

Ulcerative Colitis

Chronic ulcerative colitis may occur at any age Often of abrupt onset with frequent bowel movements, the disease usually involves the descending colon by numerous ulcerations which may perforate These patients are often dehydrated malnourished, and anemic thus decreasing the myocardial reserve and enhancing the anesthetic hazard

from the disease during the first year of life elective surgery is usually delayed However, this is not possible in one fifth of the cases of mucoviscidosis which develop *meconium ileus* This acute intestinal obstruction the surgeon attempts to cure by removing the inspissated meconium

The anesthetic evaluation and management should take cognizance of

1 Preanesthetic x rays of the chest for evidence of pulmonary involvement

2 Avoidance of drying agents in the premedication to minimize viscosity of the pulmonary secretions

3 Restoration and maintenance of fluid and electrolyte balance, since fluid and salts are lost through vomiting and sweating Excessive loss of sodium chloride in the sweat in a hot environment may cause heat prostration and rectal temperature should be monitored preoperatively operatively and post operatively Inadequate fluids may cause a further increase in the viscosity of the bronchial secretions

Duplications of the Digestive Tract

Duplications of many parts of the digestive tract can occur Gross reported 68 lesions of various shapes and sizes arising from the esophagus, stomach small intestine and large intestine Most of them are intimately attached to the adjacent portion of the digestive tract

ACQUIRED DISEASES OF THE DIGESTIVE TRACT

Appendicitis

Appendicitis can occur in infants under one year of age, but the majority of cases are found in children from six to twelve years of age The younger the infant the more serious the disease since infants and young children lack sufficient omentum to localize the disease Of concern to the anesthesiologist are the rise in temperature, increase in pulse rate, vomiting metabolic acidosis with the appearance of acetone and diacetic acid in the urine Children exhibit this ketosis much more frequently than adults since even very short periods of carbohydrate deprivation markedly reduce the carbohydrate metabolism Incompletely oxidized fatty acids, β-hydroxybutyric and diacetic appear in the blood stream and urine, with a small amount exhaled as acetone through the lungs The increase of ketone acids in the blood reduces the concentration of bicarbonate ion Inasmuch as dehydration is also present in many instances of acute appendicitis, it is advisable to give 5 per cent dextrose in water parenterally before surgery

Food

The anesthesiologist must always ask the question—when did the patient last eat? Glucose in water or other sweetened clear fluids can be given by mouth up to two hours preoperatively Solid foods, including milk, should be discontinued orally six hours preoperatively in infants and children

In emergency surgery which by necessity has to be performed soon after a meal, an effort is made to wash out the patient s stomach However, complete emptying is rarely accomplished, and during anesthesia, if premonitory signs of emesis such as salivation and retching occur, the infant should be put immediately on his side in the Trendelenburg position or even held up by the feet and the oropharynx suctioned An uncooperative child may be anesthetized lightly while on his side in the Trendelenburg position the pharynx stimulated with the tip of the suction and emesis promoted As a final precaution, the child is anesthetized, and an endotracheal tube inserted to guard the airway It is our custom to use the latter method

Distention of the Stomach

The stomach may become distended by air (Fig 72) and cause considerable respiratory embarrassment, and in these circumstances a stomach tube should be passed Air ingestion is greatest when there is obstruction to respiration In all instances of intestinal obstruction, such as pyloric stenosis atresia of the bowel, intussusception, strangulated hernia or volvulus, the infant should be anesthetized with a stomach tube in place since silent regurgitation of stomach contents may be overlooked until cyanosis draws attention to the aspiration of stomach contents into the lungs

Bowel Habits

A history of a recent acute diarrhea warns of dehydration and severe loss of sodium and potassium Fluid and electrolyte imbalance should be at least partially corrected before anesthesia

Enema

An ordinary soapsuds enema is advisable the night before the operation if the child has not had a bowel movement that day Postoperative

CONGENITAL DISEASES OF THE LIVER

Obstructive Jaundice of the Newborn

The obstruction in the biliary system may be due to atresia, red blood cells, inspissated bile cysts or tumors These marasmic infants with obstructive jaundice may have cirrhosis of the liver, with portal hypertension splenomegaly elevated direct and indirect van den Bergh, reduced prothrombin, and moderate anemia The urine is darkly pigmented, acid in reaction, with traces of albumin Surgery is undertaken with the hope that a correctable cause can be found however in most instances the surgeon is disappointed These deeply jaundiced malnourished infants live a surprisingly long time and endure prolonged anesthesia and surgery except in the terminal stages of their disease

CONGENITAL DISEASES OF THE ABDOMINAL WALL

This classification includes inguinal hernia, diaphragmatic hernia and umbilical hernia the most serious of which are the congenital hernia of the diaphragm and the omphalocele

Omphalocele

From the sixth to tenth week of fetal life the viscera protrude into the umbilical cord After the tenth week the abdominal cavity enlarges and the viscera are withdrawn from the umbilical cord into the abdominal cavity If this withdrawal does not occur, the viscera remain in the umbilical cord and give rise to omphalocele The condition is a surgical emergency

During surgery when the attempt is made to replace the viscera in a small abdominal cavity serious cardiovascular impairment may result from the elevated venous pressure and subdiaphragmatic pressure In doubtful cases the surgeon may cover the intestine with skin alone

SPECIFIC PREPARATION OF THE DIGESTIVE TRACT FOR ANESTHESIA AND SURGERY

Following the evaluation of the digestive tract the anesthesiologist should make certain preparations for the management of the anesthesia He is particularly concerned with the presence of solid food in the stomach distention of the stomach the bowel habits and the necessity of an enema

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Fig 72 Distention of stomach and intestines by air in newborn with considerable encroachment on thoracic cage

hyperthermia thereby is reduced to a minimum In addition cleansing of the lower bowel prevents evacuation on the operating room table should a rectal anesthetic agent be employed

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CHAPTER 8

EVALUATION OF THE UROGENITAL SYSTEM

NORMAL ANATOMY

The kidney is composed of one to two million units called nephrons, each nephron consisting of a glomerulus, a fine network of capillaries enclosed in a funnel-shaped collecting structure, which continues as the proximal convoluted tubule. This descends in a long loop in the medulla of the kidney, subsequently ascending to the proximity of the glomerulus to form the distal convoluted tubule. This, in turn, empties into the collecting tubule, which finally ends in the pelvis of the kidney.

The glomerulus gets its blood supply from afferent arterioles of the renal artery. The afferent arteriole divides into the capillaries of the glomerulus, and these unite to form the efferent arteriole. Surrounding the proximal and distal convoluted tubules, the efferent arteriole divides into many branches, which finally unite to form the renal vein.

At birth, the kidney, although possessing all its nephrons, shows considerable immaturity of glomeruli and tubules. The capillary tuft of the glomerulus remains covered with fetal epithelium until the second year of life. The kidney of the premature infant may have a large number of even more immature nephrons. The bladder of the infant and young child is located at a higher level in the abdominal cavity than in the adult, therefore at times either it may be palpated or an area of dullness percussed.

CONGENITAL DISEASES OF THE UROGENITAL SYSTEM

The urological system, like all other systems of the body, is subject to varieties of underdevelopment. The ectopic kidney fails to ascend from

the sacral to the lumbar region while the polycystic kidney is filled with congenital cysts Extrophy of the bladder is exemplified by a urinary bladder with absent anterior wall and with urine appearing directly on the skin surface, in surgical correction, primary closure may be attempted or a new bladder may be constructed from intestine However excisional correction may be necessary in patent urachus where the urinary tract between the bladder and umbilicus persists beyond fetal life

Obstructive Congenital Malformations

Obstructive congenital malformations are comparatively common in children and include congenital absence of one ureter reduplication of ureter, megaloureter bladder neck obstruction urethral valves ureteral diaphragm, meatal stricture and occasionally atony of the bladder associated with spina bifida

Hypoplastic Kidney

Infants may be born with agenesis of the kidney and although they have been able to survive intrauterine life, their extrauterine existence is short lived Potter has been able to show that agenesis of the kidneys often accompanies a particular facies in which the ears are soft, flabby and arise in a more caudad position The eyes are far apart, and the epicanthic fold is prominent

Associated with the hypoplastic kidney many other renal and bladder anomalies or diseases may be present, such as polycystic kidney, hydronephrosis pyelitis or cystitis Generally, the diagnosis is not confirmed until cystoscopic examination and pyelogram or cystogram have been performed

NORMAL PHYSIOLOGY

The function of the kidney is to maintain homeostasis of the body working constantly to keep the body fluid and its various constituents within normal range The kidney maintains this relative stability by filtering the complete blood volume many times daily through the glomeruli and selectively reabsorbing urinary water or urinary substances into the blood At times, the tubules excrete substances and water from the blood into the urine

Filtration through the glomeruli is a physical process governed by the pressure in the glomerular capillaries This pressure is in turn, opposed by the osmotic pressure of the proteins in the plasma while transfer of substances in the tubules from the urine to the blood or from the blood

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CONGENITAL DISEASES OF THE UROGENITAL SYSTEM

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It has been hypothesized that the high organic acid values are due to the anerobic breakdown of glucose and glycogen into lactic acid with the liberation of energy Lactic acid never breaks down to its final end products, carbon dioxide and water, consequently the lactic acid level in the blood is high It is believed that the administration of glucose by supplying an anerobic source of energy lengthens the survival time of the newborn when subjected to hypoxic conditions

	Premature		*Newborn*		*Child*	
	CATION	ANION	CATION	ANION	CATION	ANION
HCO_3		16 8		22 0		27 0
Cl		103 0		107 0		104 0
Organic acids (lactic pyruvic)		17 8		3 0		6 0
Inorganic acids (SO_4 and PO_4)		6 1		5 5		3 0
Protein		12 4		14 8		16 0
Na	?		142 0		142 0	
K	?		7 8		5 6	

Fig 73 Serum electrolytes of the premature normal newborn and child (The information in this figure is adapted from many tables and from the text of *Chemical Anatomy Physiology and Pathology of Extracellular Fluids* by J L Gamble)

The normal adult kidney in its maintenance of acid-base balance has three methods of conserving body base

1 By conversion of dibasic phosphate to monobasic phosphate However the infant kidney has a marked incapacity to change dibasic phosphate to monobasic phosphate In fact it has only 10 per cent of the adult concentration of phosphate in the urine

2 By excretion of free acids This method is well developed in the newborn with part of the following acids being excreted in the free state uncombined with base

Normal
uric acid
lactic acid
hippuric acid
pyruvic acid

Abnormal Organic Acids
acetoacetic acid
β hydroxybutyric acid

to the urine is governed by both physical and humoral factors Many of those processes are familiar to the reader such as salt and water retention regulated by the adrenal cortex and posterior pituitary gland

Most of the evidence obtained from kidney function tests, such as inulin, urea and para-aminohippuric acid clearance, indicates that the infant has better developed glomerular filtration processes than tubular function and that he is far less efficient in maintaining the volume and composition of his body fluids than the child over two years of age This fact accounts for the infant s daily fluctuations of body fluids and their composition

The immaturity of kidney function in the infant readily allows over hydration when saline solutions are administered, for the infant kidney cannot easily excrete sodium or chlorides Therefore, the infant s weight can readily and rapidly increase from such overhydration, with sudden pulmonary edema as the ever-lurking consequence The newborn, particularly seems to have fewer postoperative complications when fluids are given sparingly rather than abundantly

There is in the infant an insensible fluid loss from the lungs and the skin of 1 0 ml per kg of body weight per hour, double the loss for the adult In fact one of the advantages of premedication with a belladonna derivative such as atropine or scopolamine is the conservation of body fluids by maintaining insensible fluid loss at a minimum We have all observed the copious diaphoresis and respiratory tract secretions during anesthesia when the drying agent has been omitted

Acid base Balance Function of the Kidney

In order to recall the function of the kidney in maintaining acid base balance it is best to review briefly the serum electrolytes of the prematurely born the normal newborn and the child In Figure 73 are tabulated the differences in the cations and the anions of the serum Sodium, the principal cation is 142 mEq per liter in the newborn and child, while potassium is 7 8 mEq per liter in the newborn and only 5 6 mEq per liter in the child

The concentration of anions in the newborn suggests a metabolic acidosis chiefly due to an excess of the inorganic acids However Figure 73 indicates only 3 mEq per liter of organic acids, mostly pyruvic and lactic acids, for the full-term newborn It is suggested by some although not fully substantiated that the figure should be higher based upon findings that the premature infant shows a very high concentration of organic acids in the serum about 18 mEq per liter

Blood 1 No anemia
2 Total plasma protein reduced serum albumin often markedly reduced and may be lowered to about 0 4 gm per 100 ml of blood (normal is 4 gm per 100 ml of blood) serum globulin normal or increased
3 Cholesterol increased
4 Sedimentation rate increased
5 Serum calcium decreased because of the low protein level non ionized blood calcium being usually bound to the protein anion
6 Chlorides increased
7 Serum sodium bicarbonate and pH reduced
8 Nonprotein nitrogen and blood urea nitrogen within normal limits if there is no added complication, urea para aminohippuric acid and inulin clearances are normal or close to normal

X ray of chest shows a small heart

Moderate premedication should be employed since such a patient often has a marked reduction in his basal metabolism X-rays of the chest may reveal pleural effusion which should be reduced before surgery, if possible as should any ascitic fluid be aspirated

Lower Nephron Nephrosis

This is characterized by severe oliguria or anuria, hypertension and uremia It may be seen after blood transfusion reactions, extensive burns or crushing injuries Clinically it is often accompanied by shock with accompanying elevation of the nonprotein nitrogen, sodium, and potassium levels

Pediatricians treat these patients with just enough fluid to compensate for losses from the digestive pulmonary, and integumentary systems With the onset of diuresis, there may be a noticeable loss of electrolytes, usually evident by the appearance of hypochloremia and of course, requiring proper and immediate electrolyte replacement

It is seldom necessary to anesthetize these patients in the anuric phase, however should it be necessary to anesthetize a patient recovering from a lower nephron nephrosis the inclusion of an antihistaminic in the premedication will reduce considerably the postoperative emesis This is particularly true in many burned patients who come frequently to the operating room for debridement and skin grafting

Acute Glomerulonephritis

Often arising one to three weeks following an upper respiratory infection or sore throat the typical pathological lesion is a hyperemic inflam

3 By the manufacture of ammonia from glutamine or amino acids The ammonia replaces the fixed bases in the tubules and returns them to the blood This production of ammonia in the kidney to replace fixed bases, such as sodium and potassium is exceedingly well developed in the infant and ammonia production is even greater than in the adult

In summary, the newborn kidney has the following characteristics

1 Decreased glomerular filtration
2 Decreased ability to reabsorb sodium potassium chloride and water
3 Increased excretion of pyruvic and lactic acid
4 Marked difficulty in converting monobasic to dibasic phosphate
5 Well-developed ammonia production mechanisms
6 Ability to excrete free acids well

Of main concern to the anesthesiologist in the maintenance of acid base balance is the coordination of kidney function and respiration Any decrease of alveolar ventilation elevating the pCO_2 of the blood (respiratory acidosis) stimulates the distal tubules of the kidneys to reabsorb base bicarbonate The converse is also said to occur, that is any increase of alveolar ventilation thus lowering the pCO_2 of the blood (respiratory alkalosis) restrains the distal tubules of the kidney from reabsorbing base bicarbonate

Micturition

During the first few months of life micturition is governed by a spinal reflex It is an automatic act and has an abrupt beginning without straining and a sharp ending without dribbling It is not unusual for the young infant to initiate unexpectedly a forceful stream on the operating room table However, as the infant grows older higher centers and eventually the cerebral cortex govern the spinal reflex so that by the age of three years the child usually has complete control of micturition

ACQUIRED DISEASES OF THE KIDNEY

Nephrosis

This disease is characterized by an insidious onset of edema with oliguria but no hypertension hematuria or measurable impairment of kidney function Patients with nephrosis are usually irritable

Laboratory Tests

Urine Marked proteinuria due to increased permeability of glomerulus to protein

body to this degree of acidity. It might be advisable to prepare the chronic glomerulonephritic patient for anesthesia and surgery by gradually reducing the acidosis with intravenous antiacidotic solutions.

However, since these patients are often on the verge of tetany, the anesthesiologist in situations where marked imbalance is present should be prepared to administer 1 ml of 10 per cent calcium gluconate slowly intravenously at intervals throughout the operation until a maximum of 0.1 gm per kg of body weight has been given.

Chronic Pyelonephritis

In early childhood practically all patients with chronic pyelonephritis have a history of pyuria, usually associated with some focal or purulent nephritis. The pediatrician generally examines the child for kidney damage by restricting his fluid intake for 24 hours and determining the urinary specific gravity at the end of that period. It should be normally at least 1.022. If chronic nephritis is already present, a specific gravity of at least 1.022, normally achieved, cannot be obtained. Similarly, the blood urea nitrogen nonprotein nitrogen coefficient, usually within the region of 0.44, may reach levels as high as 0.90, chiefly because of the rise in blood urea nitrogen values. As was observed in chronic glomerulonephritis, the carbon dioxide of the blood may be low, the calcium low, and the phosphate high, while in chronic pyelonephritis the urine has a tremendous number of pus cells and markedly positive albumin reaction.

These children are anesthetized for investigation by retrograde pyelography. Since the disease is a chronic one, ample time is afforded to correct the low serum calcium and to administer antibiotics, usually selected on the basis of urinary cultures and sensitivity studies.

Embryoma of the Kidney (Wilms' Tumor)

Seen in early infancy and childhood, this is a tumor, metastasizing to the lungs, which arises from the kidney tissue. Usually smooth in outline and painless, it may grow to a large mass before detection. The kidney function is normal, but urinalysis may show some red blood cells, while the intravenous pyelogram ordinarily shows some distortion of the renal pelvis and calyces. Preoperatively, it is sometimes difficult to distinguish an embryoma from a neuroblastoma which may arise from the medulla of the adrenal gland.

matory lesion of the glomerulus There may be hypertension accompanied by headache, vomiting and visual disturbances With the hypertension cardiac failure is often present

Laboratory Tests

Urine Marked proteinuria with casts and blood
Blood 1 Anemia
2 Rapid sedimentation rate for about three months during the acute phase of the disease then in the favorable cases the rate prolongs
3 Elevated nonprotein nitrogen
4 Decreased salt and fluids (these should not be restricted in patients with acute glomerulonephritis for the tubules are unable to reabsorb sodium potassium chloride and water)

The anesthetization of a patient with acute glomerulonephritis is far more serious than the anesthetization of the patient with nephrosis Any anemia should be corrected before surgery, and cardiac failure treated If the accompanying signs of hypertensive encephalopathy are present, opiates should be omitted from the premedication and barbiturates reduced

Chronic Glomerulonephritis

Following the acute phase of glomerulonephritis, the glomerulus may become scarred The nephron may permanently lose its capacity for the tubular reabsorption of sodium and water, and concentration in the distal convoluted tubule becomes impossible Consequently a fixed low specific gravity is observed in the urine The urea clearance at this time will be similar to the inulin clearance because of the incapacity of the tubular cells to absorb urea

The chronic nephritic often remains anemic and has a metabolic acidosis due to the increase in his blood of acid phosphate sulfate and organic acids while there is a corresponding reduction in bicarbonate The rise in the serum acid phosphate is accompanied by a fall in the calcium, and sometimes this drop may be sufficient to produce tetany The serum potassium also falls If there is serious involvement of the kidney tubules, the body loses a valuable substitute for fixed bases, namely ammonia with ammonia reduction there is a lack of a substitute for sodium in the urine

Many of these chronic nephritics remain in a state of acidosis and hypoproteinemia In fact they may become accustomed to a carbon dioxide as low as 9 mEq per liter only possible because of the adaptability of the

Normal and Abnormal Constituents of the Urine

Normally, the urine contains the cations—sodium, potassium, calcium, magnesium and ammonia and the anions—chloride, acid phosphate, sulfate organic acids creatinine uric acid, urea, and a small amount of dissolved carbon dioxide However, other substances such as barbiturates may be excreted in the urine

Specific Gravity

On the first day of life, the specific gravity varies from 1 008 to 1 018, although the average is 1 012 (Fig 75) Rising during the first three days

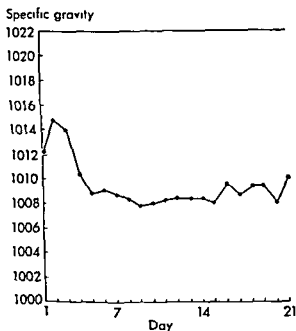


Fig 75 Specific gravity of urine in the first twenty-one days of life (Thomson J Observations on the Urine of the Newborn Infant *Arch Dis Childhood* **19** 169 1944)

to reach an average of 1 015, the specific gravity then drops on the fifth day to about 1 009 where it stays for approximately the remainder of the first month of life increasing later on

Perhaps of more importance is the determination of renal urinary concentrating ability and this can be ascertained only by restricting fluid intake Any patient unable to concentrate urine requires further investigation

pH

The pH of the urine varies considerably from that of the blood plasma, and the newborn is often on the acidotic side with a pH of approximately 5 0 often due to the conservation of bases by the kidney with an excre-

URINALYSIS

All patients before anesthesia and surgery should have a urinalysis because a pathological condition such as diabetes or nephritis may be detected. In one instance a child following a tonsillectomy failed to recover consciousness. Postoperative catheter specimen of urine suggested that the child was in a diabetic coma, subsequently confirmed by physical and blood examinations. Routine urinalysis is valuable from a medicolegal point of view, should postoperative complications arise, in providing evidence that a particular condition did or did not exist preoperatively.

Urinalysis should include volume of urine, specific gravity, pH, protein, glucose, acetone, diacetic acid and a microscopic examination of the sediment from a centrifuged specimen.

Volume of Urine

Because there is little fluid intake, the excretion of urine in the first three days of life is low (Fig 74), and the total loss of fluids from the

Day	*Volume (ml)*	*Range (ml)*	*Number of Infants*
1	19 5	0–68	35
2	20 6	0–82	29
3	36 0	0–96	26
4	64 8	5–180	26
5	103 3	1–217	23
6	124 5	42–268	19
8	151 0	59–330	17
10	190 0	106–320	6
12	227 0	207–246	2

Fig 74 Average daily volume of urine in first twelve days of life (Thomson J Observations on the Urine of the Newborn Infant *Arch Dis Childhood* 19 169 1944)

intestinal tract and from the skin and lungs causes a loss in weight during the first three days. During this period it may be difficult to obtain a specimen of urine because of the low excretion and since many of the operations in this age group are emergencies they are done quite often without waiting for a urinalysis. On a weight basis, the newborn and the child excrete more urine per kg of body weight than does the adult. The edematous premature, however, may excrete much more urine than the normal newborn, as the edema subsides.

fusion of 5 per cent dextrose in water, or in the young infant, by 2 5 per cent dextrose in water subcutaneously

However, if the acetone bodies occur in the urine together with glucose, then the patient s condition should be investigated, for this is suggestive of diabetes Occasionally, diabetics may have abdominal pain resembling appendicitis They may, indeed, have appendicitis, or other conditions requiring surgery If so, great care must be exercised in the preparation of the diabetic child for surgery (See Chapter 9, ' Evaluation of the Endocrine System ' pp 162–63)

Microscopic Examination

A microscopic examination is performed to determine the presence of erythrocytes, leucocytes, epithelial cells and/or casts, for they are indicative of renal disease

The selection of anesthetic agents in patients with urological disease is a delicate one for no one agent or combination of agents as yet available is ideal Ether does not appear to be the most salutory in many cases since it produces metabolic acidosis in all infants under one year and in 50 per cent of children from one to twelve years of age Primarily, ether acidosis results from the production of acid phosphate, sulfates and lactic acid, while, in addition, renal function is further suppressed by this anesthetic agent Yet, to consider agents, the barbiturates frequently exhibit a prolonged effect when administered in the presence of kidney dysfunction, while cyclopropane may result in respiratory acidosis by reason of respiratory depression

Preventive measures must be instituted by the anesthesiologist to reduce the deleterious effects of the agents and technics he must employ For example he should make every effort to avoid increasing an already mounting metabolic acidosis by the superimposition of a respiratory acidosis thus endotracheal anesthesia is generally selected in these cases in order to reduce dead space Ventilation is enhanced either manually or mechanically and elimination of the anesthetic agent is facilitated usually by a wise choice of agent one eliminated primarily and readily through the pulmonary system Only after careful evaluation and meticulous attention to details can the anesthesiologist hope to help these often chronically ill patients through a surgical procedure

tion of free acids, indeed, a fortuitous arrangement of nature However, if there has been an ingestion of base, the urine swings to the alkaline side

Unless a freshly voided specimen is collected, pH determinations are of no value, for bacteria in themselves can produce ammonia in the urine, thereby giving a higher pH

Protein

The anesthesiologist should know how to interpret proteinuria Is it physiological or pathological? Premature infants usually have protein in their urine while the full term newborn may have proteinuria after the first day and persisting even into the second week Orthostatic proteinuria due to emotion, fatigue, and during adolescence is physiological even though the cause is not clear, but believed due to disturbances in renal circulation As the name implies, protein appears in the urine when the patient is in the upright position

On the other hand there may be significant proteinuria in severe dehydration heart failure Wilms' tumor pyelonephritis acute or chronic glomerulonephritis, nephrosis lower nephron nephrosis from burns or crush injuries peritonitis osteomyelitis and upper respiratory infections

Glucose

Glycosuria is encountered if the child has ingested large amounts of sweetened fluids candies or has been given a large quantity of glucose intravenously A large amount of the glucose passes out with the glomerular filtrate and exceeds the quantity which can be reabsorbed by the tubules

The presence of glucose in the urine is often pathological if accompanied by acetone bodies, and must be so interpreted until proven otherwise

Acetone Bodies

If acetoacetic and β hydroxybutyric acids occur in the urine without glycosuria, it is an indication that there is an increase in fatty acids in the blood thus revealing a metabolic acidosis Frequently young infants will show acetone bodies and diacetic acid in their urine because of incomplete combustion of fats This occurs with the omission of one or two feedings since the glycogen stores are depleted to such an extent that the infant utilizes his fat This should be corrected before surgery by intravenous in-

CHAPTER 9

EVALUATION OF THE ENDOCRINE SYSTEM

Although the field of endocrinology is still undergoing many changes with a number of blank pages to be filled we will outline briefly some of the present-day concepts regarding the following glands thyroid, parathyroid pancreas, pituitary, and adrenal

THYROID GLAND

Hyperthyroidism

This does not often occur before twelve years of age and is similar in manifestation to hyperthyroidism in the adult If removal of the gland is anticipated the patient should be prepared carefully for surgery with antithyroid medication sedation and bed rest

Hypothyroidism

In this group are the congenital type or cretinism and acquired juvenile hypothyroidism, exhibiting mental sluggishness dry skin large tongue poor muscle tone hypothermia bradycardia with cardiomegaly, and decreased pulse pressure Tissues are myxedematous These patients are given their usual dosage of thyroid on the day of surgery however sedative drugs in the preanesthetic medication are reduced in accordance with the severity of the disease, since the basal metabolic rate is subnormal

CONGENITAL MALFORMATIONS OF THE SEX GLANDS

Cryptorchidism

Cryptorchidism or nondescent of the testes, may be bilateral or unilateral As a rule surgical treatment is carried out before puberty, and seldom is any effect on the development of the child noted except that created by his awareness of the fact that he is not quite normal

Heterosexual Development

Even though there are many different classifications in heterosexual development the most frequent ones coming to the attention of the anesthesiologist are those which demonstrate abnormalities of the external genitalia Such patients are usually presented at an early age for a biopsy of their gonads chiefly for the purpose of determining whether to bring up the children as males or females In other instances such as clitoridectomy, the approach to the emotional problem of the patient the avoidance of erection and the prevention of blood loss are considerations for the anesthesiologist

TUMORS OF THE SEX GLANDS

Tumors of the gonads, manifested in infancy or childhood may be either benign or malignant and seldom have any profound or undue effects upon general systemic bodily functions unless as a result of massive growth or advanced metastatic infiltration

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with the severity of the disease and complications For elective surgery, the child should enter the hospital several days prior to surgery and the diabetes brought under optimal control

PITUITARY GLAND

Hypopituitarism

Panhypopituitarism or Simmond s disease is rare in childhood, resulting usually from destruction of the pituitary As expected, organs such as the adrenal cortex the thyroid and the gonads which are under the control of the pituitary, may show hypoactivity

Diabetes Insipidus In this disease there is hypofunction of the posterior lobe of the pituitary with deficiency of the pressor and antidiuretic principle producing polyuria intense thirst, constipation dehydration and decreased cardiovascular efficiency The specific gravity of the urine is low below 1 012 and usually remains below 1 005 even when the patient is tested by dehydration However, some cases respond to the pressor and antidiuretic principle of the posterior pituitary with an increased urinary specific gravity

Froehlich's Syndrome (Adiposogenital Dystrophy) and Laurence Moon-Biedl Syndrome Both of these syndromes demonstrate obesity and sexual infantilism but in addition, there may be increased intracranial pressure and often a congenital heart lesion associated with Froehlich s syndrome The possibility of increased intracranial pressure suggests that a harmful overdosage of opiate or opiate like drugs or other respiratory depressants could easily be given

Hyperpituitarism

Gigantism Caused by eosinophilic adenoma of the pituitary, this condition is exceedingly rare in children There is overactivity of the growth hormone of the pituitary gland, producing elongation of the bones and increased stature early in life No other functions seem to be affected at this time

Cushing's Syndrome Cushing s syndrome or basophilic adenoma of the pituitary produces hyperadrenocorticism Typical signs and symptoms are enlargement of the tissues around the face, neck and trunk hypertension weakness and pain in the back An excess production and retention of salt and water cause the edema Hirsutism acne and clitoral enlargement may also accompany the disease

PARATHYROID GLANDS

Hyperparathyroidism

Usually an adenoma or diffuse hyperplasia of the parathyroid glands causes this disease although glomerulonephritis pyelonephritis, and congenital anomalies of the urogenital tract are possible causes There is hypercalcemia with the accompanying bradycardia and shortening of the Q T interval hypotonicity of muscles, nausea vomiting and constipation The increased excretion of calcium and phosphorus may cause polyuria and polydypsia and the formation of urinary calculi of calcium phosphate To prevent further formation of renal stones fluids should be forced and calcium intake restricted Osteitis fibrosa cystica may occur as a result of loss of calcium from the skeletal system

Occasionally, surgical extirpation of the tumor is attempted

Hypoparathyroidism

Hypoparathyroidism a tetany producing condition, is characterized by numbness and twitchings of the extremities carpopedal spasm, laryngospasm and in severe instances there may be loss of consciousness and convulsions Blood calcium level is decreased and phosphorus increased, with decreased urinary excretion of both calcium and phosphorus

Treatment before anesthesia with calcium parathyroid extract, or vitamin D should reduce the danger of laryngospasm and convulsion during anesthesia

PANCREAS

Although the infant produces a relatively high quantity of insulin during the first two years of life, the newborn has a lessened insulin response In keeping with this low response newborns of diabetic mothers may have pancreatic islet cell hypertrophy and yet demonstrate hypoglycemia however often an asymptomatic hypoglycemia

Diabetes mellitus in the child is a far more serious disease than in the adult because of severity prognosis and difficulty of control Ketosis is common in the child, as are wide variations in the blood sugar therefore, all juvenile diabetics require insulin and close regulation of diet

Surgery in the diabetic child presents little hazard over that of the surgery per se as long as it is recognized that there are certain problems peculiar to the diabetic patient The nature of these problems will vary

and diagnosis is usually made with phentolamine (Regitine) or benzodioxane test Surgical removal of the tumor is generally attempted but may be prolonged because of difficulty in locating the tumor The anesthesiologist should select an anesthetic agent compatible with an excess amount of epinephrine and norepinephrine and after removal of the tumor, should be prepared to sustain the blood pressure with norepinephrine

Adrenal Cortical Steroids

The active isolated adrenal cortical steroids are corticosterone (compound B) 17-hydroxy-11-dehydrocorticosterone (cortisone) (compound E) 17 hydroxycorticosterone (hydrocortisone) (compound F), 11-dehydrocorticosterone (compound A) 17-hydroxy-11-desoxycorticosterone (compound S), 11-desoxycorticosterone (Doca), and aldosterone As far as is known these steroids play, to varying degrees, an important role in the restoration of many functions of the body when these functions have been disturbed 17-hydroxycorticosterone (compound F), 11-desoxycorticosterone, 17-hydroxy-11-desoxycorticosterone (compound S), and aldosterone play a major role in regulating volume and composition of body fluids especially when other factors are causing a fluid and electrolyte imbalance Both desoxycorticosterone and aldosterone stimulate the renal tubules to reabsorb sodium from the urine However, desoxycorticosterone may increase potassium excretion and produce a hypokalemia, which may result in necrosis of both myocardial and skeletal muscles over a long period of time Doca reduces the irritability of the central nervous system and potentiates the action of anticonvulsants The dangers from the administration of Doca lie in too much reabsorption of sodium and water which fortunately can be prevented by adrenocorticotropic hormone (ACTH) Overdosage of Doca will also produce a hypertension which likewise can be controlled by hydrocortisone Aldosterone even though much more powerful than Doca in causing tubular reabsorption of sodium and water does not have the same danger of over-reabsorption as Doca So far artificial synthesis of aldosterone has resisted all efforts

To understand the diseases caused by the adrenal cortex, the anesthesiologist must possess a knowledge of hypocorticism (Addison's disease) and hypercorticism The latter occurs in Cushing's disease adrenal cortical tumors and prolonged administration of ACTH cortisone, or hydrocortisone

Laboratory findings show elevated serum sodium and decreased chlorides, elevated red blood cell count low eosinophil count (below 50 per cu mm), and the urine contains sugar

If removal of the tumor is anticipated, the pediatrician generally prescribes hydrocortisone

ADRENAL GLANDS

Immediately before birth the adrenals of the fetus are grossly enlarged and at birth are twenty times the relative adult size The mature cortex consists of three zones zona glomerulosa, zona fasciculata and an inner most zone the zona reticularis However in the fetus and young infant a large proportion of the additional mass of the adrenal gland is due to the presence of a histologically distinct fetal cortex which commences to involute by the third or fourth day, becoming one half the original size by the end of the second week and completely disappearing by the end of one year The zones of the true cortex particularly the zona glomerulosa increase in size and at the end of one month are two or three times their original size The large size of the adrenal glands however, is not reflected to any great extent by increased function The urinary 17-ketosteroids which usually reflect adrenal cortical function are slightly increased the first few days of life to an average of 1 2 mg per 24 hours Nevertheless by the end of the first month this has decreased to 0 5 mg and remains at that level for one year Very small premature infants do not show the increased 17-ketosteroids at birth

There are two physiologically distinct parts of this extremely important gland—the cortex and the medulla The cortex secretes corticoids and androgens while the medulla secretes the vasopressor substances norepinephrine and epinephrine The adrenal cortical steroids or corticoids are not completely understood in structure or function, but since they appear to play such an important role in homeostasis, a brief attempt must be made to delineate the present day knowledge

Pheochromocytoma

This tumor of the medulla of the adrenals or of other sympathetic ganglia is rare in children but it produces the same reactions which would be expected from excess secretion of epinephrine and norepinephrine namely, headaches palpitation, nausea vomiting and diarrhea precordial pain, dilated pupils rapid pulse hypertension and cardiac enlargement Many of the signs and symptoms are of a transitory, paroxysmal nature,

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urinary nitrogen exist while there may also be ketonemia and a deposition of fat around the face neck and trunk

Electrolytes show normal sodium and potassium values but calcium metabolism is disturbed causing osteoporosis and tetany Similar to pyloric stenosis with vomiting there may be a metabolic alkalosis and, more specifically, a hypochloremic and a hypokalemic alkalosis

Increased urinary excretion of histamine is seen, and inflammatory reaction to infection is often absent

As in hypocorticism, there is muscle weakness which can be ameliorated by hydrocortisone or cortisone but not in this instance by Doca

Irritability of the nervous system may be greater and in some instances even a psychosis may arise, or in children convulsions may occur Certain dangers exist such as decreased pain perception, probably due to the lack of inflammatory reaction even with severe lesions as in ruptured peptic ulcer Anesthesiologists who monitor their patients with the EEG should remember that there is a reduction in amplitude, regularity, and continuity of the basic alpha activity, while, in addition a slower alpha wave of 3 to 7 cycles per second is noted

A decrease in the lymphoid tissue of the body and a lymphopenia occur, but there is increased production of polymorphonuclear leucocytes The eosinophil count is 50 or less per cu mm Polycythemia, hypercoagulability, and even hypertension exist in hypercorticism

Apart from the above characteristics, hypercorticism either from endocrine therapy hyperplasia or adenoma may cause menstrual disturbances in the female impotence in the male virilism in the very young hirsutism but with loss of hair on the scalp, acne, capillary fragility, and poor healing of the tissue because of the lack of fibroblasts, granulation tissue formation and poor vascularization There is also an antipyretic effect, even in the presence of a bacteremia

Other Adrenal Cortical Disturbances

In addition to the recognized diseases of the adrenal cortex, there are certain conditions probably related to the stress syndrome in which there is a decrease of blood corticoids These occur in rheumatic fever rheumatoid arthritis and glomerulonephritis However, should the body undergo trauma, there may be an elevation of corticoids, as seen in severe burn cases with subsequent elevated blood corticoid levels and hypokalemia

It has been reported that nitrous oxide and ether will elevate blood corticoids, but that pentobarbital sodium (Nembutal) and morphine will

Hypocorticism (Addison's Disease)

This disease syndrome shows widespread disturbances throughout many body organs and systems, particularly affecting metabolism and water and electrolyte balance

Carbohydrate metabolism is upset, with reduction of liver and muscle glycogen, retardation of gluconeogenesis and hypoglycemia, particularly if there is a reduced intake of food Protein disturbance becomes manifest in reduced urinary nitrogen with lowering of food intake Fats however, are completely utilized, and therefore, ketonemia is absent

Electrolyte imbalance is evidenced by hyponatremia due to the failure to reabsorb sodium, hyperkalemia and suppression of the reabsorption of water by the kidney tubules Anemia is common, and although the hematocrit and total plasma protein are elevated, a low blood volume exists In addition, there may be a decreased cardiac output with lowered blood pressure and an actual reduction in cardiac size Other abnormalities include a rise in histamine content of the tissues, diminished efficiency of skeletal musculature and hyperplasia of the lymphoid tissue with lymphocytosis

Fortunately these patients are usually well controlled with a high salt diet and adrenal corticosteroid replacement therapy An attempt is made to retain the patient in eucorticism although general health measures must be employed and full reliance must not be placed upon the administration of endocrine preparations

Hypercorticism

Modern anesthesiologists must grasp fully the elements of this condition since today so many diseases are treated with steroid therapy, and also since more surgical patients with Cushing s disease adrenal cortical tumors or adrenal hyperplasia are encountered The complexity of adrenal function does not yet allow predictable response to hormonal administration in the operating room but an understanding of patient responses to stress will be of value in therapy

In hypercorticotropic states there is marked disturbance of normal physiologic processes especially the metabolic processes Hyperglycemia glycosuria an increased tolerance to insulin (probably due to increased gluconeogenesis from protein) a decreased utilization of glucose and a decreased renal reabsorption of glucose are all manifestations of altered carbohydrate metabolism Increased protein catabolism and increased

CHAPTER 10

EVALUATION OF THE NERVOUS SYSTEM

. VELOPMENT

The cerebral cortex is the last portion of the infant nervous system to nature, as is borne out by histological evidence that the gray matter is a thin layer at birth, and the cortical structure is immature with only ual myelinization Thus the activities of the newborn such as motion ying and sucking are predominantly reflex and can occur even in the sence of the cortex

Fusion of suture lines and fontanelle closure bear a distinct relation- to specific disease entities Since the skull bones are not fused at the cranial vault is capable of marked variation in capacity, ac- ounting, for example, for the huge cranium often seen in the hydro- ephalic, while the undeveloped and unexpanded brain results in the mall head of the microcephalic Closure of the anterior fontanelle may e delayed in cretinism rickets and hydrocephalus but on the other land, in microcephalus and prematurity the fontanelle closes earlier than l

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and Cranial Nerves in the Neonatal Period

Examination of the cranial nerves in infants discloses deficiencies in- volving the third, fourth and sixth nerves as manifested by very little

decrease them It has also been reported that any surgical procedure can cause an elevation of the serum corticoid, for example, in a tracheo esophageal fistula repair the serum corticoid has been seen to rise from 2 μg preoperatively to 100 μg per 100 ml postoperatively Much further and prolonged investigation of the effects of anesthetic agents on the endocrine system must be done before a thorough understanding is pos sible and the literature of the next few years will doubtless do much to enlighten us about such problems

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Although mobile in the first few months of infant life the cranial bones become relatively fixed by fibrous fusion at the fifth or sixth month progressing to bony fusion along the suture lines by the end of the fourth year

Somatic and Cranial Nerves in the Neonatal Period

Examination of the cranial nerves in infants discloses deficiencies involving the third fourth and sixth nerves as manifested by very little

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reflex, by which the newborn searches for the nipple, and the sucking reflex, evoked by stimulation of the lips or face The sucking reflex remains until the end of the first year

Tapping the bed near the infant will normally demonstrate the Moro reflex, *one of the most reliable Abduction and extension of all four* extremities occur, followed by adduction and flexion Although normally disappearing before the fifth month the Moro reflex may either be retained by defective children for years or be entirely absent

One of the reflexes of posture and equilibrium, the tonic neck reflex, can be observed by turning the head to one side whereupon the extremities become extended on that side and flexed on the contralateral side—the typical 'boxer position This reflex should disappear approximately at the end of the sixth month In considering another massive head-trunk response, it is to be noted that extension of the head causes opisthotonus, while sharp flexion of the head produces flexion of the whole body

Cerebrospinal Fluid in the Infant

A window for evaluation of intracerebral pressure is provided by the anterior fontanelle for bulging at this site indicates increased pressure, as contrasted with the depression often seen in dehydration and dural leaks

Often a source of alarm to the uninformed, the xanthochromia present at birth is normal

Electroencephalographic Patterns

It has been said that the electroencephalogram is of little value in children under three to four years of age Although rhythmic brain waves are practically absent in the newborn in a few weeks relatively slow, irregular deflections appear, with increasing amplitude in the first few months (Fig 77) Later the fundamental alpha waves appear These waves gradually decrease in amplitude but increase in frequency The individual s characteristic pattern does not fully develop until about the tenth year, but persists throughout life

CONVULSIONS

Young infants do not convulse readily However later in infancy and in young childhood convulsions are much more common than in adults

Convulsions in the early ages and young childhood may have many causes There is the idiopathic type about which nothing definite can be determined Infections of the brain such as meningitis, encephalitis, brain

coordination of the extraocular muscles before the third month and a minor degree of incoordination persisting for several months However, the corneal reflex, activated by the fifth nerve, is present at birth, as is the gag reflex, which is dependent upon intact ninth and tenth nerves

Anatomically in the newborn the spinal cord extends to the third lumbar vertebra, whereas in the adult it ends between the first and second lumbar vertebra (Fig 76) The somatic motor nerves appear to be de veloped, but pain perception is diminished for at least the first few days

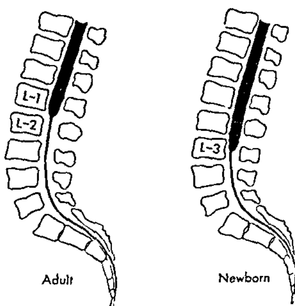


Fig 76 Level of spinal cord in adult and newborn

Reflexes in the Neonatal Period

In accordance with the immaturity of the nervous system, it may be noted that the deep reflexes are present in general but many of the superficial reflexes may be lacking

For example ankle clonus is not normally present at birth and the cremasteric reflex is difficult to elicit Abdominal reflexes are present in only about 30 per cent of newborns and in many instances do not become established until six months to one year of age Showing variable response in the first few months the plantar reflex may result in either flexion or extension with predominance of extension between the first and second years The knee jerk is also difficult to elicit at birth but a mass response suggests cerebral injury The grasping reflex present at birth disappears between the second and fourth month

Two active and useful reflexes about the head and neck are the rooting

biturate lowering the body temperature to normal and providing glucose before and during surgery, thus avoiding hypoglycemic convulsions Water intoxication may be treated by the oral ingestion of sodium chloride or by the preoperative intravenous administration of 3 per cent or 5 per cent sodium chloride solution then following the electrolyte pattern to achieve a normal balance of chlorides and carbon dioxide Hyperventilation lowering the pCO_2 as in brain tumor cases, can be avoided by allowing rebreathing by mask Rarely seen prior to anesthesia are convulsions from increased pCO_2 or respiratory acidosis although they are an ever-present danger during anesthetic maintenance

Hypocalcemia from hypoparathyroidism renal insufficiency, infantile rickets, steatorrhea, postacidotic hypocalcemia (which may arise with too vigorous a correction of the acidosis of chronic glomerulonephritis) or, finally, in hypoproteinemia and low vitamin D blood level (as occurs in young infants) may be treated with high calcium-low phosphorus diet calcium gluconote or lactate and vitamin D However in some instances, parathyroid extract may be necessary

Epilepsy

This condition is differentiated from other convulsions by the repetition of a pattern of reaction of cerebral origin without demonstrable organic brain lesion Usually beginning in childhood, the onset of epilepsy is very rare before two years of age The cause of epileptiform seizures on the other hand may be a developmental defect microgyria vascular anomalies scars from past injuries, or areas of cortical atrophy

The well known grand mal seizure may be preceded by an aura, followed by loss of consciousness pallor, dilated pupils rolled-up fixed eyes violent tonic muscular spasm with an outcry cyanosis bladder and rectal evacuation This tonic spasm is followed by clonic convulsions After these attacks the patient usually suffers impairment of consciousness and memory

Petit mal seizure is the most deceptive type It usually consists of staring spells with momentary loss of consciousness and little or no convulsive movements In one instance such a patient had been given premedication the petit mal occurring just prior to anesthesia A period of apnea followed requiring pulmonary ventilation with oxygen In this instance the parents were unaware of previous attacks but the father recalled having similar spells as a child and stated that the child was subject to crying out suddenly at night

abscesses, congenital anomalies such as hydrocephalus porencephaly, and microcephalus, brain tumors, trauma and cerebrovascular accidents such as embolism thrombosis, and hemorrhage are moderately common causes Generalized infection such as pneumonia, scarlet fever, and malaria, with their sudden high fever, may be preceded by convulsions Of the infectious diseases, however, pertussis is the commonest cause, resulting in convulsive seizures by one of three mechanisms gastric tetany produced by excess vomiting, resulting in metabolic alkalosis, hypoxia and increased carbon dioxide tension, cerebral hemorrhage

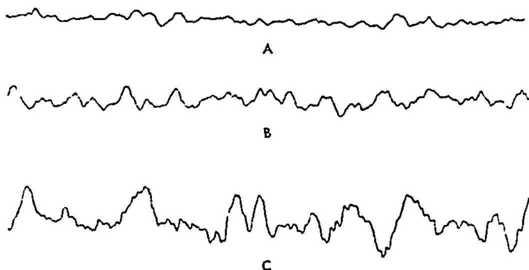


Fig 77 Electroencephalogram (A) One week old (B) eight weeks old (C) three months old

Uremia and lead poisoning may cause convulsions Hypoxia or hypercarbia hypocalcemia and hypoglycemia are other convulsive triggers One which may be overlooked is water intoxication These individuals have hypochloremia and hypocarbia therefore a hyponatremia, but the cells themselves have too much water and this intracellular edema is probably the basis of the convulsions

Vitamin B_6 deficiency may occur if the mother has not been given vitamins during the latter part of her pregnancy or if there is a deficiency of vitamin B_6 in the artificial feeding This deficiency of B_6 or pyridoxin may cause convulsions in the infant

Anesthesiologists adopt many methods to avoid convulsions before during and after anesthesia The idiopathic type which is closely akin to epilepsy, can be controlled by increasing the barbiturate in the premedication Convulsions due to high temperature can be controlled by bar-

skull (oxycephaly) because of growth in the skull bones in sites other than at the borders, as occurs normally In this instance, the growing brain becomes cramped for space Without surgical correction, these patients show the effects of increasing intracranial pressure, cortical atrophy, mental retardation, exophthalmos, and even cranial nerve injuries resulting in loss of smell, taste, and visual sensation

Cranium Bifidum This is a congenital defect in the midline of the skull, either in the frontal or occipital bones There may be no herniation of the intracranial structures but it is usually associated either with meningocele or meningoencephalocele

Spina Bifida This is a congenital defect, more commonly present in the lumbosacral or the cervical region wherein there is failure of closure of the vertebral arches It, too, may show no herniation of cord contents, but more commonly a meningomyelocele or meningocele is encountered, with the concomitant threat of rupture and infection further complicated by the paresis of the lower extremities and sphincters often noted in meningomyelocele Clubfoot is often an associated deformity in these patients

Congenital Amyotonia (Oppenheim's Disease) This disease occurs in the newborn and is characterized by a generalized type of muscular weakness Because spinal motor nerves are commonly affected, there is weakness of the muscles of the neck thorax, abdomen back, and lower extremities In severe cases the diaphragm is the only muscle of respiration not affected These patients have grave respiratory difficulty with marked indrawing of the thorax on inspiration and are prone to pulmonary infection Fortunately it is a very rare disease but in instances of paradoxical respiration it must always be kept in mind

Mongolism (See Chapter 1 Evaluation of the Body as a Whole p 6)

Cerebral Palsy This is the most common crippling disease of children The central nervous system damage may be prenatal, natal, or postnatal in occurrence About one third of these children are mentally retarded, but the chief characteristic of the disease is a disturbance of voluntary motion varying degrees of spastic or flaccid paralysis being present The spasticity indicates involvement of the pyramidal tract and is by far the most common type Some have hyperactivity and distorted activity of the voluntary musculature where the lesion is in the extrapyramidal tract and the basal ganglia In the most severe cases there are irritability, feeble respirations rigidity vomiting malnutrition and sometimes convulsions

Epileptiform cases often show mental deficiency especially if attacks have been frequent Since such patients are often subject to violent outbursts of emotion, it is wise to prepare them for anesthesia by anticonvulsant drugs to reduce the likelihood of a disturbance which might initiate a seizure prior to anesthesia For elective surgery it is much safer to schedule the operation for a time when the patient is not on a ketogenic and dehydrating diet (frequently encountered as treatment for epilepsy), for this adds considerably to the dangers of anesthesia and, as one might expect severe collapse may occur

OTHER DISEASES OF THE NERVOUS SYSTEM

Congenital Defects and Developmental Diseases

Hydrocephalus The cerebrospinal fluid is produced by secretion from the choroid plexuses in the ventricles of the brain In the roof of the fourth ventricle it passes through the foramina of Luschka and Magendie into the subarachnoid space, where it surrounds the surface of the brain and spinal cord Subsequent reabsorption occurs through the arachnoid villi, however, any obstruction to the flow of spinal fluid so that it cannot reach the arachnoid villi will cause an accumulation of fluid, giving rise to hydrocephalus and increased intracerebral pressure

This condition usually appearing within two or three months of birth is manifested early by the widened tense fontanelles with abnormally separated suture lines which are delayed in their closure The infant may be lethargic but showing increased tonicity of the extremities and increased tendon reflexes Because of lethargy and increased intracranial pressure sedatives and anesthetic agents should be reduced, in fact, except for a mild antisecretory agent premedication should be omitted in many of these cases

Microcephaly This is the small head type with the receding forehead There is early closure of the fontanelles ossification of cranial sutures the brain being small, with poorly developed convolutions marked mental retardation, and a tendency to convulsions Several children in one family may be affected

The opposite to this is macrocephaly an exceedingly rare condition However, these children too are mentally retarded and prone to convulsions

Craniostenosis This is a congenital defect in which the cranial sutures form fixed bony unions either before birth or soon after, causing a tower

or internal surface of the cranial bone Usually no treatment is necessary as it gradually disappears by absorption

Vascular Disorders

Children are also subject to vascular disorders similar to those seen in adults Congenital heart cases may have cardiovascular accidents such as thrombosis or embolus, and will show typical paresis, usually of the muscles of the face on the side of the lesion and the muscles of the arm and leg on the opposite side

Infections of the Central Nervous System

Meningitis Anesthesiologists may be called in consultation for control of the convulsions of meningitis These patients have increased intracranial pressure, producing bulging fontanelles in the small infant, irritability, projectile vomiting, blurred vision, slow pulse, and the state of consciousness varies from hyperirritability to sleepiness and even coma Some children have a high fever and may even be in shock In control of these convulsions, it is important to note any increased intracranial pressure, since small doses of depressant drugs may produce apnea, while in shock-like states barbiturates must be used with extreme caution

In the common meningococcic type of meningitis, usually of sudden onset with very high temperature, the anesthesiologist should be aware of the possibility of concomitant myocarditis These patients may have hemorrhagic tendencies with hemorrhage of the adrenal glands resulting in the typical shock state of the Waterhouse-Friderichsen syndrome

Pneumococcal, streptococcal, and staphylococcal meningitis may have the foci of infection in the sinuses, lungs or ears The onset is more gradual than in the meningococcal type, and in this type the anesthesiologist may be required to anesthetize the patients for surgical drainage of an abscess or empyema in the lungs or elsewhere in the body

Meningitis originating from *Hemophilus influenzae* usually occurs in children under two years of age Although it may proceed to coma the onset is gradual However these children also may have a bacteremia, later in the disease forming a subdural abscess requiring drainage

Poliomyelitis Of the viral infectious diseases of the central nervous system poliomyelitis predominates but since the introduction of prophylactic poliomyelitis vaccine, the frequency of the disease is markedly decreasing

In the acute phase of the paralytic type of poliomyelitis, anesthesiolo-

Temperature regulation is so impaired that atropine must be used cautiously, for the child may develop a high fever Antibiotics must be used often, for even mild infections may cause a marked elevation of temperature All require adequate preanesthetic sedation except those with respiratory depression who should be premedicated with great care

Another type of cerebral palsy may show atonia or flaccidity of the muscles These children are almost invariably retarded, and this type should be considered by anesthesiologists to be very similar to amyotonia congenita

Trauma

Trauma to the cranium at birth or later in life may result in contusion of the brain tissue intracerebral hemorrhage, or compression of the brain tissue either by subarachnoid subdural or epidural hemorrhage

Intracerebral Hemorrhage The hemorrhages may be into the brain substance and if massive enough, the infant does not survive With the use of vitamin K during the latter part of pregnancy the infant s prothrombin time is decreased thus affording some prophylaxis against hemorrhage

Subarachnoid Hemorrhage The commonest lesions confronting the anesthesiologist are the subarachnoid hemorrhages caused either by trauma or spontaneous rupture of an aneurysm which usually occurs later in childhood These patients may be lethargic and even unconscious and diagnosis is usually made by blood in the spinal fluid

Subdural Hematoma Blood collects between dura and arachnoid and may be due either to birth trauma or physical trauma later in life The damage here is to subdural veins and the leak is often slow the lesion gradually becoming evident some time after the injury

Epidural Hemorrhage This is usually caused by bleeding from veins or the middle meningeal vessels Often there is a history of trauma with a period of unconsciousness, a lucid interval and then increased drowsiness The pulse may be weak blood pressure low, and respirations irregular These patients are frequently seriously ill, requiring immediate surgery accompanied by blood transfusions and other supportive therapy Respiratory depressants must be omitted in the premedication

Depressed Skull Fracture This is a common type of traumatic injury in the newborn If there are no signs of increased intracranial pressure these patients present no real anesthetic problem

Cephalhematoma A relatively common birth injury cephalhematoma is an accumulation of blood beneath the periosteum either on the external

Tumors of the Central Nervous System

Primary malignant tumors of the brain are one of the most frequently seen of all malignancies in infants and children, exceeded in frequency only by leukemia.

Craniopharyngioma, a slow growing tumor usually originating in the region of the optic chiasm, constitutes 6 per cent of brain tumors.

On the other hand, approximately 75 per cent of brain tumors are gliomas, and of these 60 per cent are astrocytomas. A slow growing, cystic type of tumor, they are usually situated in the posterior fossa. These patients show cerebellar signs of ataxia, nystagmus, deafness, sometimes weakness and incontinence, with nuchal rigidity and suboccipital tenderness. Cranial sutures may be widened and cranial bones atrophied by increased pressure on the brain. These cases have a favorable prognosis if the tumor can be completely removed.

Medulloblastomas, occurring generally in boys three to six years of age, form 35 per cent of gliomas. They are also posterior fossa tumors, however, the prognosis is grave.

Five per cent of gliomas are spongioblastomas, usually cerebral tumors, markedly invasive, and showing similar effects of pressure on the skull bones. The prognosis is exceedingly grave, as surgical removal is almost impossible, and death usually ensues soon after surgery.

Although a somewhat rare occurrence, tumors originating in other parts of the body can metastasize to the brain. Hypernephroma is one of the commonest tumors in children to result in cerebral metastases. Malignant melanoma may also metastasize, however, melanomas rarely become malignant until puberty.

Obviously all these brain tumors show signs of increased intracranial pressure, and respiratory depressants should be omitted from the premedication. It is also worthy of note that tumors in the posterior fossa lie close to the respiratory centers, and damage from surgical manipulation is likely.

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gists may be required to supply oxygen and artificial respiration during the performance of the tracheostomy outside the respirator usually done under local anesthesia An important feature to remember is to give these patients no sedatives but to employ a drying agent such as scopolamine. Since these children cannot communicate with the anesthesiologist, he should attempt to gain their confidence while they are in the respirator then use a bag and mask for artificial respiration during the tracheostomy later switching to an endotracheal tube which will fit the tracheostomy tube When using the bag and mask it is important to remember that under ventilation of the lungs causes considerable distress and these patients are far more comfortable if the lungs are well inflated with each manual compression of the breathing bag.

Children who have residual paresis of the intercostal and abdominal muscles following poliomyelitis are now having surgical correction, with support to the abdominal muscles being supplied by criss-cross strips of fascia. These patients must be given no sedative in the preanesthetic medication, but require larger doses of belladonna drugs to reduce the abundant secretions in their respiratory tracts They are intubated without the use of a muscle relaxant, in fact, very light anesthesia with maintenance of some spontaneous respiration is desirable but respiration may be lightly assisted, if necessary

Post-poliomyelitis patients for tendon transplant operations with no respiratory muscle weakness are treated as are other patients depending upon the level of activity since it is inactivity which decreases myocardial tone It is important that these patients recover rapidly from anesthesia and have frequent endotracheal suctioning, for they are prone to respiratory infections and aspiration of foreign material

Other diseases such as mumps measles and chickenpox may be complicated by encephalitis, but these children seldom, if ever need the aid of the anesthesiologist, except for the treatment of convulsions tracheal aspiration, or respiratory failure

Brain Abscesses: Brain abscesses usually originate in the ears lungs, bones, air sinuses or furuncles Increased intracranial pressure occurs resulting in the usual neurological signs If conservative therapy has not been entirely successful, these patients may require drainage of the brain abscess It must be remembered, however that if intracranial pressure is elevated, respiration can be depressed readily by any of the sedatives.

CHAPTER 11

EVALUATION OF THE ORGANS OF SPECIAL SENSE (EYE AND EAR)

Since the anesthesiologist's evaluation of the organs of special sense is related in the majority of cases to patients who are presented specifically for surgery upon the eye or the ear, the diseases of these organs are not discussed here in detail, but the anesthetic management for operations upon the eye and ear will be found in Section IV, Anesthetic Management of Surgical Procedures (pp 414–22)

The following diseases are common in infants and children ptosis of the eyelids nasal lacrimal duct obstruction, strabismus cataracts, glaucoma, and retrolental fibroplasia Many of these disorders of the eye may have a marked effect on the patient's personality and consequently are corrected by surgery before permanent personality scars occur

In Chapter 1 (p 5) the psychological effects of deafness were discussed In addition there are several types of deformities of the ear which tend to produce personality changes in children There are however very few conditions of the ear which have a general systemic effect on the patient except chronic mastoiditus which may lead to some anemia

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SECTION

II

ANESTHETIC AGENTS, TECHNICS, AND EQUIPMENT

CHAPTER 12

ANESTHETIC AGENTS

In this chapter is outlined the pharmacology of anesthetic agents as well as the reasons for our preferences in pediatric anesthesia

GASEOUS ANESTHETICS

NITROUS OXIDE

Advantages

1 A pleasant rapid induction and recovery with no adverse effects

2 A pleasant induction for unpleasant drugs such as ether, trichlorethylene and halothane (Fluothane)

3 A good analgesic for mildly analgesic anesthetics such as Fluothane, barbiturates and tribromoethanol

4 A nonflammable gas to be combined with other nonflammable agents such as Fluothane trichlorethylene, heavy preanesthetic sedation, intravenous opiates or opiate-like drugs, rectal or intravenous barbiturates rectal tribromoethanol or local anesthetic agents

5 Compatible with all muscle relaxants

6 Compatible with adrenergic drugs

7 Does not depress or stimulate the circulation or respiration

8 Does not increase the loss of blood

9 Does not cause nausea or vomiting

10 Serves as a diluent for high oxygen concentration in prolonged operations

4 Prone to cause laryngospasm, either during induction or emergence This is very rare with controlled respiration, and it can be alleviated readily with intramuscular or intravenous succinylcholine

5 Marked depression of respiration, requiring assisted or controlled respiration to avoid respiratory acidosis and postoperative shock

6 Produces poor muscular relaxation with unassisted spontaneous respiration There is marked improvement in the muscle relaxation when cyclopropane is administered with adequate pulmonary ventilation

In spite of these disadvantages, cyclopropane is one of the safest of all the potent anesthetic agents used in pediatric anesthesia, *providing* the anesthesiologist fulfills three requirements (1) monitors the heart continuously to avoid overdosage, (2) uses endotracheal anesthesia, and (3) avoids hypoventilation

VOLATILE LIQUID ANESTHETICS

DIETHYL ETHER

Advantages

1 Easily portable and readily available in an emergency
2 Wide margin of safety in healthy patients
3 Stimulates respiration
4 Infrequency of severe laryngospasm
5 In light doses maintains myocardial tone, supposedly by output of epinephrine
6 Provides muscle relaxation with only mild depression of respiration and circulation
7 Reduces clotting time
8 Can decrease irritability of the heart
9 Compatible with epinephrine

Disadvantages

1 Flammable and explosive
2 Tachycardia
3 Ill patients with some degree of myocarditis either nutritional or infectious in origin, show early reduction in tone of the myocardium somewhat abrupt cardiac dilatation, and peripheral dilatation, with bradycardia and reduced cardiac output (Fig 78)

Disadvantage

1 Inability to provide suitable surgical conditions without causing hypoxia

Nitrous oxide is widely used in pediatric anesthesiology because its only fault impotency can be overcome by combining it with a small amount of more potent anesthetic agents, and even then such a combination provides one of the least toxic anesthetic methods[8]

CYCLOPROPANE

Advantages

1 Nonirritating

2 Pleasant, rapid induction and emergence (40 per cent cyclopropane produces unconsciousness within two or three breaths)

3 Cyclopropane and artificial pulmonary ventilation produce apnea and muscle relaxation in a few minutes thereby providing excellent conditions for intubation

4 Produces a moderate degree of skeletal relaxation for surgery

5 Does not reduce may even increase cardiac tone and output

6 Blood sugar and electrolyte and fluid balance remain normal

7 No increase in fixed acids of blood

8 Does not produce hemoconcentration or encourage thrombosis

9 Increases very little the loss of body fluids through the respiratory tract or by sweating

10 Does not interfere with peristalsis

11 Compatible with muscle relaxants

Disadvantages

1 Increased bleeding at operative site

2 Flammable and explosive Explosiveness can be reduced by the addition of helium or other inert gases

3 Increased cardiac irritability giving rise to bradycardia premature beats ventricular tachycardia or ventricular fibrillation Irritability may be decreased with barbiturates procaine, ether quinidine or atropine Cardiac irritability may be augmented by carbon dioxide retention digitalis, hypothermia, or vasopressors particularly those with a catechol nucleus such as epinephrine norepinephrine or 3,4-dihydroxyphenylpropanolamine hydrochloride (Cobefrin)

DIVINYL ETHER (VINETHENE) and ETHYL VINYL ETHER (VINAMAR)

Advantages

1 Good analgesics
2 Nonirritating induction agents
3 Rapid induction, but slower than cyclopropane
4 Do not increase the irritability of the myocardium
5 Readily portable
6 Wide margin of safety
7 Respiration not markedly depressed if deep planes are avoided
8 No laryngospasm

Disadvantages

1 Weak agents
2 Flammable and explosive
3 Nausea and vomiting frequently seen
4 Convulsions common during induction
5 Useful only for short periods of analgesia
6 Cause considerable increase in secretions in the respiratory tract, and may cause diaphoresis if administration is prolonged
7 Do not produce muscle relaxation satisfactory for abdominal surgery
8 Cause acidosis

Both divinyl ether (Vinethene) and ethyl vinyl ether (Vinamar) are disappearing from the field of pediatric anesthesiology, readily understandable if the disadvantages of these agents are considered for there are too many other agents with superior attributes Both these agents are relegated to the position of induction agents for open drop ether, which also is seldom employed by the experienced pediatric anesthesiologist

ETHYL CHLORIDE

Advantages

1 Quick pleasant induction and recovery with minimal nausea and vomiting
2 Quickly volatilized

4 Hemoconcentration—slight increase in viscosity of blood

5 Can cause nonfatal convulsions early in anesthesia either from the ether or carbon dioxide retention

6 Can cause convulsions late in anesthesia from a combination of de hydration, starvation, hyperthermia, and carbon dioxide excess This type may be fatal

7 Severe loss of body fluids in skin and lungs if no belladonna pre medication has been given, and very severe loss if morphine alone has been given

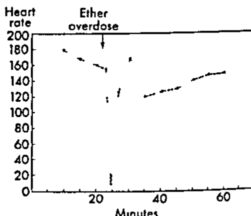


Fig 78 Diethyl ether—marked brady cardia resulting from overdose

8 Moderate metabolic acidosis in all infants under one year of age, producing a mean fall in bicarbonate of 5 2 mEq per liter, mild metabolic acidosis in 50 per cent of patients one to twelve years of age Metabolic acidosis is due partly to production of lactic acid and partly to increased phosphates sulfates and keto acids

9 Fall in serum potassium

10 Deep ether with curariform drugs can cause a prolonged apnea

11 Rise in blood sugar up to 100 per cent

12 Severe postoperative nausea and vomiting

13 Induction and recovery from anesthesia may be very prolonged

14 To avoid respiratory depression, hypoxia, and prolonged induction, preanesthetic sedation should be minimal when diethyl ether is used with open drop technic

Because it stimulates respiration ether is the safest agent for the unskilled anesthesiologist However because of its pungency, myocardial depression gross disturbance of bodily functions, often prolonged induction and recovery times with postoperative nausea and emesis, and unpleasant memory for the patient, skilled anesthesiologists prefer other agents

4 Increases irritability of the myocardium and is incompatible with epinephrine
5 Cannot be used with carbon dioxide absorbers
6 Prolonged induction and recovery
7 Increased salivary secretion without belladonna premedication

Trichlorethylene serves a useful role as a more potent nonexplosive inhalation agent when used as an adjunct to nitrous oxide anesthesia

HALOTHANE (FLUOTHANE)

Advantages

1 Nonflammable and nonexplosive
2 Pleasant odor
3 Can be used with the absorption technic
4 Rapid comfortable induction
5 Less tendency to produce laryngospasm than many other agents
6 No increase in salivary or bronchial secretions
7 No increase in diaphoresis
8 Sufficient laryngeal and jaw muscle relaxation for intubation
9 Compatible with succinylcholine and decamethonium (Syncurine)
10 Decreased bleeding even without hypotension
11 Decreased contact cardiac irritability may be useful in open heart surgery
12 Minimal postoperative nausea and vomiting
13 Recovery from anesthesia is rapid

Disadvantages

1 Not a good analgesic
2 Marked tendency to produce hypotension with increasing concentrations, severe blood loss, traction on viscera postural changes curare-like drugs (tubocurarine gallamine) or in ill patients
3 Respiratory depression
4 Moderate abdominal muscle relaxation
5 When used with vasopressors with a catechol nucleus such as epinephrine or Cobefrin, it can cause ventricular fibrillation
6 Atrioventricular dissociation seen frequently
7 Postoperatively diuretic hypokalemia can occur

3 Sinus rhythm can be maintained if the patient is adequately atropinized and deep planes are avoided

4 Excellent analgesic

Disadvantages

1 Low boiling point A considerable amount is volatilized and may displace the oxygen in the inspired air

2 Cardiotoxic It may cause severe cardiac depression or ventricular fibrillation

3 Not compatible with epinephrine

4 Poor muscle relaxant

5 May cause an abrupt drop in blood pressure due to dilatation of the heart and reduced myocardial tone with consequent reduction in cardiac output In instances of cardiac arrest, death may be avoided by inflating the lungs rapidly with oxygen, opening the chest and performing cardiac massage

In the hands of one experienced in the administration of ethyl chloride this agent still remains a most satisfactory one Experienced anesthesiologists very rarely administer an overdosage of ethyl chloride Nevertheless it is used infrequently since it has a narrower margin of safety than many other agents

TRICHLORETHYLENE

Advantages

1 Nonflammable and nonexplosive

2 Easily administered by means of an inhaler

3 Useful for very brief operations such as myringotomy, abscess drainage or to fortify nitrous oxide anesthesia when nonexplosive anesthetic technic is mandatory

4 Good analgesic

5 Minimal postoperative vomiting

6 Readily portable

Disadvantages

1 Unpleasant odor

2 Does not produce muscle relaxation

3 Tachypnea

Disadvantages

1 Difficulty in cannulating small veins in chubby arms

2 Poor analgesics

3 No rapid reversal in instances of overdosage

4 Danger of direct depression of myocardial tone, dilatation of heart, marked reduction of cardiac output, and reduced oxygen saturation of the blood (Fig 79) They are extremely hazardous in congenital heart disease cardiac failure anemia, shock, and myocarditis from infection malnutrition, or in other patients with reduced myocardial reserve Cardiac depression can be partly counteracted by use of vasopressor drugs

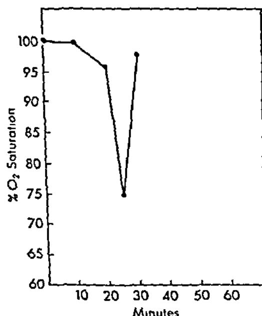


Fig 79 Barbiturates given intravenously causing abrupt fall in oxygen saturation as recorded on oximeter

5 Dilatation of peripheral vascular system

6 Respiratory acidosis from hypoventilation

7 Laryngeal reflexes hyperactive may cause severe, sustained laryngospasm with sustained spasm of chest muscles and marked reduction in alveolar oxygen It is not easily relieved except by muscle relaxants

8 Hazardous in patients with history of asthma, in whom the barbiturates may cause bronchospasm and spasm of muscles of respiration combined with laryngospasm It may be overcome by use of muscle relaxant given intravenously or intramuscularly

9 Inadequate muscle relaxation for abdominal surgery

10 Prolonged hypnosis can occur in all patients, with hypothyroid disease or when large amounts of thiobarbiturates are given

As a rule, the patient is anesthetized with a 2 liter flow of oxygen, a 2 liter flow of nitrous oxide, and a 2 per cent concentration of Fluothane During the initial trials with Fluothane the nonrebreathing technic was used but as the anesthesiologist gained experience with this agent, he adopted the circle filter technic and controlled respiration The vaporizers that we presently use are the copper kettle, Fluotec, and F N S The nitrous oxide is required to provide analgesia with the safer lower concentrations of *Fluothane*

The heart is monitored continuously with a precordial stethoscope and the blood pressure is monitored continuously during induction and prior to intubation, for we have discovered that even a pink looking patient may have inaudible heart sounds unobtainable blood pressure, and im palpable pulse A rapidly decreasing blood pressure calls for an immediate decrease in the concentration or, at times, discontinuation of the admin istration of the Fluothane

Following intubation the blood pressure normally rises, and anesthesia is maintained with approximately 0 5 to 1 0 per cent Fluothane With the lowered concentration, the blood pressure usually remains at a satisfactory level

In spite of the widespread use and attendant popular acclaim of Fluothane, many anesthesiologists report incidents of severe cardiac depression requiring open thoracotomy and cardiac massage It is our opinion how ever that the number of such incidents is decreasing because the anesthesi ologist is cultivating a real appreciation of what is meant by constant moni toring of the cardiovascular system

NONVOLATILE DRUGS

BARBITURATES—THIOPENTAL (PENTOTHAL) and THIAMYLAL (SURITAL)

Advantages

1 Nonflammable and nonexplosive
2 Comfortable, rapid induction
3 Reduce irritability of myocardium
4 Fluid and electrolyte balance unchanged
5 Blood sugar is unchanged
6 Do not cause hemoconcentration, may actually produce hemodilu tion
7 Prevent nausea and vomiting postoperatively

courages its widespread use, since other equally satisfactory agents and methods for induction and sedation are now available

LOCAL ANESTHETIC AGENTS

PROCAINE

Long the standard of local anesthetic agents, procaine is still used extensively in infiltrative or block regional anesthesia in infants and children due to its relatively low toxicity and availability However, as is the case with all injectables, and more especially in children, the possibility of rapid absorption must be kept in mind The total dosage of procaine should not exceed 20 mg per kg of body weight, however, since concentration is also a major factor in absorption rate, it is advisable to keep the concentration as low as possible, preferably around 0 5 per cent

Diffusibility may be enhanced by the addition of hyaluronidase, while absorption may be retarded and effect prolonged by the addition of epinephrine, even in concentrations as low as 1 200,000

While many of the other local anesthetic agents are also topical anesthetics to the mucous membranes, procaine definitely does not possess this property and its attempted use for this purpose should be avoided

LIDOCAINE (XYLOCAINE) and TETRACAINE (PONTOCAINE)

Definitely superior to procaine in profundity of anesthesia and diffusibility lidocaine and tetracaine also have absolute toxicities greater than that of procaine therefore to avoid convulsions, somnolence and circulatory depression it is even more essential in pediatric anesthesia to use only minimal concentrations and dosages of these drugs

In contrast to procaine, these agents possess topical anesthetic properties, and frequently are used as such either by direct application or by incorporation as the active agent in water-soluble anesthetic lubricants

Except in the very small young infant who can be readily restrained, local anesthetic agents are seldom used alone, but rather frequently in combination with light inhalation anesthesia Extremely ill patients are often managed in this manner, since many of the disadvantages of deep inhalation anesthesia are thereby avoided

HYPOTENSIVE AGENTS

Following the initial wave of enthusiasm the use of hypotensive drugs has declined to the point where they are usually employed in pediatric anesthesiology only in those selected neurosurgical cases where removal

The thiobarbiturates are used in pediatric anesthesiology either as an induction agent, often preferred by older children, or as a basal anesthetic agent combined with other agents Their use is not restricted to any age group We have given them slowly intravenously, in small dosages of 5 to 10 mg to the healthy newborn infant In the mentally disturbed patient the thiobarbiturates given rectally may be most helpful in placating the patient

The thiobarbiturates can be given intermittently intravenously with curariform drugs The patient is intubated and the lungs ventilated with oxygen A rise in blood pressure indicates light anesthesia and calls for another injection of the agents

TRIBROMOETHANOL WITH AMYLENE HYDRATE

Advantages

1 Nonexplosive and nonflammable even when vaporized

2 Can be administered rectally which to most children is more comfortable than the insertion of a needle

3 No laryngospasm

4 Does not increase irritability of myocardium No cardiac arrhythmias when given with adequate oxygen

5 Slight muscle relaxation, greater than with barbiturates

6 Decreases ocular pressure

Disadvantages

1 Slight or no analgesic properties

2 Depression of tidal volume with only slight or no reduction in respiratory rate

3 Danger of hypoxia and respiratory acidosis

4 Occasional hypotension easily counteracted by a vasopressor

5 Prolonged recovery when combined with opiates

6 Unpredictable absorption via rectal route, evacuation may occur at any time after administration

7 Solutions over 3 per cent are irritating to the tissues

As a preanesthetic medication, tribromoethanol is one of the most reliable although like the barbiturates it is not analgesic and is used chiefly because of its comfortable effects It should never be given with opiates, for then the recovery period is markedly prolonged The necessity of preparing the solution each day and giving a cleansing enema dis

2 In infants, spontaneous respiration returns rapidly following apnea

Disadvantages

1 Prolonged apnea may occur—of greater incidence in children over four years of age

2 No adequate and reliable antidote for the apnea, although infusion with blood or 5 per cent dextrose in water has been recommended

3 Recovery from muscle relaxation may be abrupt and produce increased tone of the abdominal muscles and regurgitation of stomach contents with aspiration into the trachea especially if the anesthesia is light During recovery, the increased tone of the respiratory muscles may cause marked reduction in the reserve of alveolar oxygen, and hypoxia may ensue quickly

4 May produce a cholinergic-like myocardial effect with severe bradycardia drop in blood pressure and, rarely, cyanosis (Fig 80)

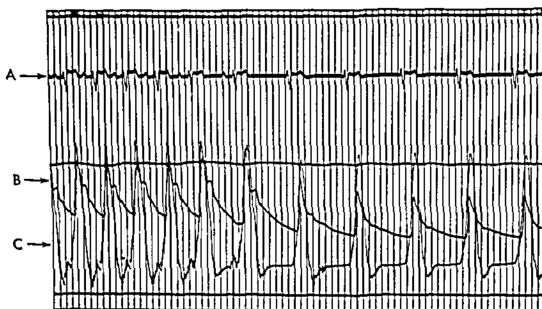


Fig 80 Succinylcholine chloride during Fluothane anesthesia *(A)* Electrocardiogram lead 2 showing bradycardia *(B)* Brachial arterial blood pressure showing drop in blood pressure concomitant with bradycardia *(C)* Right ventricular pressures only slightly reduced because of presence of pure pulmonic stenosis without shunt

5 The profound muscle relaxation may cause a pooling of blood in the abdominal viscera reducing the right atrial filling and eventually the right and left ventricular output

6 Stomach is readily distended with gas if artificial respiration is attempted with a bag and mask while abdominal muscles are flaccid

of the lesion is greatly facilitated by hypotensive technics They are used rarely in children and never in infants

MUSCLE RELAXANTS

TUBOCURARINE and GALLAMINE (FLAXEDIL)

Advantages

1 Profound muscle relaxation

2 Gradual muscle relaxation without fasciculation

3 Gallamine increases the heart rate

4 No increase in intraocular tension so advantageous in intraocular surgery

5 No systemic effects except a profound hypotension when used with Fluothane or when used in very large dosages

Disadvantages

Tubocurarine or gallamine can be used to good advantage in older children but because they tend to have a prolonged effect in infants and young children they are rarely employed in this age group

They may also have a prolonged effect in patients with myasthenia gravis myasthenia gravis tendency, with deep ether anesthesia, or in conjunction with magnesium sulfate giving rise to dangerous postoperative respiratory complications such as hypoventilation and atelectasis

If examination of the patient s chest at the end of anesthesia discloses inspiratory intercostal lag an attempt should be made to restore the tone of the respiratory muscles This is done by first administering atropine *and increasing the heart rate followed by intravenous edrophonium* (Tensilon) or neostigmine (Prostigmin) to restore muscular tonus The atropine is used to block the dangerous muscarinic effects depression of the myocardium dilatation of the peripheral blood vessels excessive secretion in the respiratory tract and hyperperistalsis of the intestine with defecation and urination

SUCCINYLCHOLINE CHLORIDE (ANECTINE) (SUCOSTRIN) (QUELICIN)

Advantages

1 Short-acting depolarizing agent causing profound muscle relaxation Recovery of muscle tone is generally rapid and complete

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Succinylcholine chloride is one of the most useful agents in pediatric anesthesiology especially when muscle relaxation is required in the very young infant, since the infant tolerates succinylcholine remarkably well destroying the drug or at least neutralizing its effects so that respiration returns very shortly It has two disadvantages which can be avoided The first are bradycardia and hypotension which are more pronounced when it is combined with large doses of opiates cyclopropane, Fluothane or barbiturates On the other hand this bradycardia and hypotension are rarely seen in diethyl ether or divinyl ether anesthesia This cholinergic-like effect can be blocked with adequate atropine or scopolamine A fast heart rate does not contraindicate the administration of atropine for even a very rapid rate may be slowed considerably by succinylcholine

The second disadvantage is prolonged apnea We have never encountered this complication in infants, but have seen it twice in two four year old children who were given ether anesthesia and succinylcholine Both of these children had an apnea extending into three or four hours However, since we have been using succinylcholine in smaller dosages 0 5 mg per kg of body weight and repeating this dosage if necessary, we have not encountered prolonged apnea

DECAMETHONIUM (SYNCURINE)

Decamethonium is similar in action to succinylcholine and is a prolonged depolarizer It is used in older children for a longer lasting effect than succinylcholine has, but, similar to succinylcholine, it can cause prolonged apnea

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Control of Pulmonary Ventilation The endotracheal technic is the only method that gives reliable control of pulmonary ventilation, providing control of respiration without inflation of the stomach when the abdominal muscles are relaxed It is mandatory for all open thoracic operations, for prone positioning of the patient, and for most operations in the region of the head when the anesthesiologist is removed from the immediate operative field

Removal of Anesthesiologist from the Immediate Operative Field In operations in the region of the head and neck of the patient endotracheal anesthesia allows the anesthesiologist to be removed from the operative field, thus assisting the work of the surgeon and removing a source of contamination

Cleansing of Respiratory Tract During or at the termination of the operation, accumulations of respiratory tract secretions can be removed by using a small polyethylene catheter in infants, and a larger one in children, inserting the catheter through a suction port in the angle piece This stimulates the cough reflex and causes ejection of bronchial secretions into the trachea The deep inspiration which often follows the cough helps to inflate many alveolar ducts and alveoli We make it a rule never to leave the suction catheter in the endotracheal tube for too long, as sustained coughing reduces the oxygen reservoir in the lungs and produces hypoxia In ill patients this may be fatal Each aspiration is followed by the administration of high oxygen concentrations and often by artificial pulmonary ventilation Any bradycardia may indicate hypoxia or vagal stimulation in fact, vagal stimulation often produces a much more severe bradycardia in the presence of hypoxia

Disadvantages

Offsetting these important advantages, there are some disadvantages which to a large extent are minimized with increased experience and skill of the anesthesiologist

Obstruction to Airflow The airflow through an endotracheal tube follows Poiseuille s law, that is flow rate varies directly with the fourth power of the internal radius of the tube and is inversely proportional to eight times the length of the tube Since the internal radius of the endotracheal tube is much smaller than that of the trachea airflow in spontaneous respiration is considerably decreased As large a tube as possible with controlled breathing increases the flow rate to well above normal

also lowers body temperature and, in turn, reduces oxygen demand and carbon dioxide production, thereby decreasing the respiratory rate In addition clothes and blankets are removed to keep the patient s temperature low Small doses of sedatives give the patient rest and reduce his activity, this too reduces the oxygen demand and carbon dioxide production Quieter and slower breathing induced by the sedative prevents pulmonary edema when the airway is narrowed The alarming rising pulse rate and rising temperature are checked and reversed by this treatment

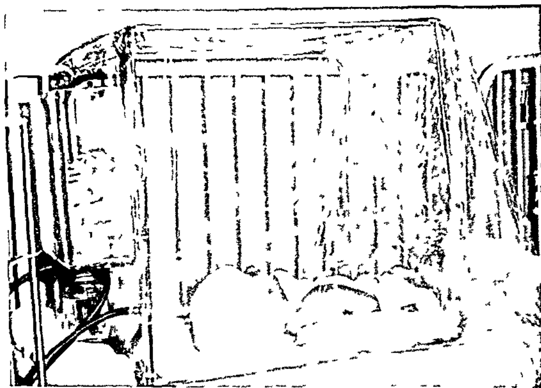


Fig 81 Cold moist oxygen enriched atmosphere for care of child with laryngitis following extubation

Seldom does an infant or child require more than two days of this treatment but careful observation is necessary to avoid other complications during this period On occasion, the sedation and inactivity may cause atelectasis and such patients must be aroused and encouraged to cough To achieve adequate coughing it may be necessary to employ endotracheal suction with a small polyethylene catheter

It is important to maintain adequate fluid intake both preoperatively and postoperatively, for dehydration causes elevated temperature rapid respiration and further irritation of any laryngeal edema which may occur Hydration is especially mandatory in hot climates where children become

Increased Risk of Trauma After extubation, there may be sore throat, hoarseness and coughing

Accidental Removal of Teeth Around the sixth and seventh year of life, the roots of the deciduous central incisors become absorbed and often the teeth are only superficially embedded in the gums If the laryngoscope is inserted roughly into the mouth, these teeth may be knocked out Although the anesthesiologist ordinarily can remove very loose teeth every effort is made to preserve them If a tooth is knocked out and cannot be located in the mouth, nasopharynx, or oropharynx a roentgenological examination of the chest is made, so that the tooth may be removed if it has lodged in the pulmonary tract Some anesthesiologists and surgeons use mouth gags, in these cases the mouth gag is apt to dislodge the canine teeth in the patient who is around ten years of age

Hemorrhage The lip may be caught between the teeth and the laryngoscope blade cutting the lip which may bleed profusely, or the blade of the laryngoscope may gouge a piece of tissue out of the posterior pharyngeal wall

Nasal intubation occasionally causes a very profuse hemorrhage but well-lubricated tubes and careful insertion tend to minimize this complication

Overdistention of Alveoli The alveoli of the newborn are easily overdistended with high pressure of gases in the trachea The hyperdistention may cause rupture of the alveolar walls (emphysema), pneumothorax or mediastinal and subcutaneous emphysema

Subglottic Edema A mild subglottic edema frequently occurring for approximately the first hour following extubation is usually due to the use of too large an endotracheal tube prolonged intubation or contaminated endotracheal tubes Although severe subglottic edema requiring tracheostomy can occur, we have had only one such event in the past ten years

However once or twice a year we see a case of very severe traumatic laryngitis necessitating our constant vigilance for several hours In such cases we request consultation with an otolaryngologist who is experienced in cases of severe traumatic laryngitis and therefore does not hastily perform an unnecessary tracheostomy Retraction and rapidity of respiration should be observed, for retraction indicates inadequate flow rate and increased respiratory rate indicates carbon dioxide retention rapid breathing through the narrowed glottis soon results in pulmonary edema and exhaustion of the respiratory muscles Employment of cold moist atmosphere is recommended which not only minimizes edema (Fig 81) but

Improper Diameter of Tube A tube whose diameter is too large for the glottis sometimes can be forced between the vocal cords, but will cause unnecessary trauma often dangerous subglottic edema On the other hand, a tube whose diameter is too small may cause partial obstruction to respiration, preventing adequate pulmonary ventilation

Improper Length of Tube Too long a tube will pass into one of the bronchi, causing atelectasis of the opposite lung, a common error with endotracheal anesthesia in infants Too short a tube also causes obstruction to respiration since on inspiration the glottis descends slightly, the tube slips out of it, and the cords approximate

Foreign Bodies On three occasions during nasal intubation, slight resistance to passage of the tube was encountered, and, on opening the mouth foreign bodies were found in the pharynx These were two beads and a small piece of rubber which the children had poked into their noses at some previous time

Prolonged Induction Intubation need not necessarily prolong the induction A skillful exposure of the glottis with a laryngoscope and a dexterous intubation by experienced anesthesiologists can be performed rapidly

A review of these disadvantages makes it apparent that they are largely the result of inexperience, and most of them can be avoided when care, skill and good judgment are used by the anesthesiologist

Equipment

For infants and children there is a wide variation in sizes of laryngoscopes and endotracheal tubes For each intubation, the anesthesiologist should select the proper size of laryngoscope, endotracheal tube and connector lubricant for the tube a doughnut-shaped headrest and a bite block In order to facilitate this selection a detailed description of this equipment will follow

Laryngoscopes The efficiency of each variety of laryngoscope is primarily a matter of experience with each type

Infants two or three weeks of age with cleft lips and palates are among the most difficult to intubate since the blade of the laryngoscope tends to slip up into the cleft and vision becomes obscured by a protruding portion of the alveolar margin A special infant's laryngoscope with a short wide blade, 8 8 cm (3½ in) long is too short for most infants over three months of age but is particularly adaptable to these very young infants

Several laryngoscopes are obtainable which have three interchangeable

dehydrated very rapidly Our incidence of laryngeal edema after intubation dropped sharply after we initiated the practice of forcing clear fluids orally until three hours preoperatively and gave copious amounts of intravenous fluids on the operating table and postoperatively

Occasionally the epiglottis itself becomes swollen and edematous causing a slight degree of respiratory obstruction postoperatively

Granuloma of the Vocal Cords Although numerous instances of granuloma of the vocal cords in adults have been reported, we have never seen or known of such a complication in infants or children

Obstructed Tubes The lumen of all endotracheal tubes should be examined to ensure patency, this is one advantage of keeping a stylet in the tube while not in use Once we noted a very small endotracheal tube with a complete diaphragm of rubber halfway along its length Then again, the lumen of small tubes while in place become blocked with inspissated blood and secretion avoidable in infants by intermittent aspiration of the endotracheal tubes

Thin walled rubber endotracheal tubes or new Portex tubes are apt to soften and kink The commonest sites of kinks are at the angle of the mouth just below the attachment of the angle piece, or in the pharynx

The lumen of the tube may become narrowed or occluded when the patient is in light anesthesia and bites on the tube, if a bite block is not inserted

Long beveled tubes may have their distal openings blocked by being pushed against the wall of the trachea or bronchus, with complete occlusion Alleviation of the blockage by rotation of the tube and slight withdrawal confirms the diagnosis

Aspirated Tubes When using nasotracheal tubes for tonsillectomy and adenoidectomy the sharp adenotome may sever the lower end of the tube This has occurred twice in our experience On one occasion the child coughed up the cut part of the tube and on the second occasion it was removed through a bronchoscope

Separation of Angle Pieces If the angle piece is too small it may slip out of the endotracheal tube The inside diameter of the angle piece should be as large as the inside diameter of the endotracheal tube If the angle piece is too large the elasticity of the rubber or plastic tube squeezes it off, and the endotracheal tube usually disappears rapidly down the trachea On one occasion no part was visible above the vocal cords nor did the patient cough in light anesthesia so bronchoscopic removal of the tube under deeper anesthesia was necessary

available in all even numbered sizes from Nos 10 to 40 French, allowing for a gradually increasing diameter with increased age of the child A gum rubber tube with a wire coil embodied in the wall is much less likely to kink and is especially useful for cases which do not permit easy access to the head during surgery (Fig 84) It is best to use a lubricated ob-



Fig 84 Gum rubber tube with wire coil reinforcement and stiff proximal sleeve to reduce kinking

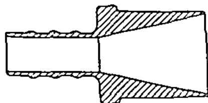


Fig 85 Cross section of DuPaco endo tracheal tube connector showing gradual tapering of lumen to minimize turbulence

turator in the lumen of this tube when it is being inserted Much of the obstruction to airflow in endotracheal anesthesia in infants is due to the small connectors and their design This difficulty can be overcome in part by inserting the largest possible connector into the endotracheal tube or better still by using one which has less turbulence because of the gradual narrowing of the connector (Fig 85) For some years Cole has been concerned with this problem of small endotracheal tubes and connectors in infants and to minimize the obstruction to airflow and also to avoid inadvertent endobronchial intubation he designed a tube (Fig 86)

blades of varying lengths In a pediatric hospital an infant laryngoscope, along with the small and medium changeable blades of the adult laryngoscope, serves all purposes

Immediately after the laryngoscope is used, the blade is carefully scrubbed with soap and water, rinsed with a copious flow of water and dried

Endotracheal Tubes and Connectors Several important features, negligible *in adult anesthesia make the choice of an infant s or child s endo-*tracheal tube difficult The wall of the tube must be as thin as is consistent with adequate firmness, especially important in tubes for smaller infants where a thick-walled tube would slow the airflow in and out of the lungs These tubes are made of either rubber or plastic A thin walled firm plastic tube called the Snowite (Fig 82) is easy to insert even during severe laryngospasm, nor does it occlude easily with kinking Nevertheless, even the Snowite when it gets warmed in the mouth may kink (Fig 83) It is

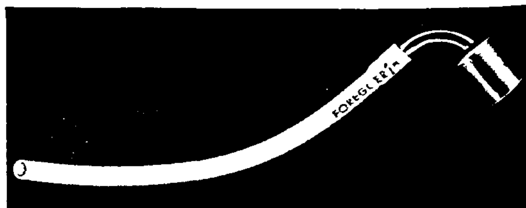


Fig 82 Snowite tube with large bore angle piece



Fig 83 Snowite tube showing kinking at end of angle piece from warmth of mouth

urements, of course, are not absolute for every patient, however, since the size of the larynx depends more on age than weight, it is surprising how closely the tube diameter can be approximated by this method

If a large number of tubes are to be used by an anesthesiologist in a morning, he prepares these tubes with their angle pieces which are seldom removed, and over the suction port of each tube he places a piece of adhesive tape on which he marks the age of the patient for whom the tube is selected, thereby enabling him to identify quickly the proper tube

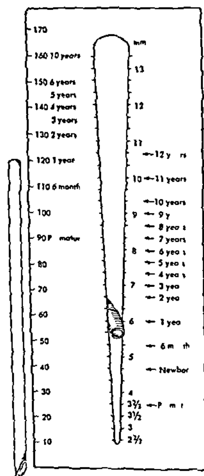


Fig 87 Modified Foregger ruler—a quick reference for diameter and length of endo tracheal tube

Cleansing and Sterilization As soon as possible after extubation, the endotracheal tubes and fitted connectors are cleansed with soap and water A pipe cleaner is passed down the lumens of the smaller tubes, in the larger tubes a small brush is used for this purpose The tubes are soaked in aqueous Zephiran 1 1000, and washed thoroughly In addition, once a week *all endotracheal* tubes are again sterilized in the above manner Coiled gum rubber tubes are kept in the refrigerator

in which the part in the pharynx and the mouth is of much larger diameter than the part below the glottis

Diameter A definite rule on the diameter of the tube used for each age group is impossible, since there is considerable overlapping An attempt is made to choose a tube large enough to fit the glottis snugly but not tightly Cachectic children who have had hypoxia or acidosis with rapid respiration tend to have a larger glottic opening than normal for their age these children ordinarily have large nares and show an accentuation of intercostal activity on inspiration For example an eleven month-old cachectic infant with a Wilms' tumor was easily intubated with a tube of 7⅔ mm diameter, which might be too large for some three year-old children In the newborn we employ a tube with either a 4 6 mm or 5 3 mm diameter The flow rate in a tube of 4 6 mm diameter is about double that in a 4 mm diameter tube

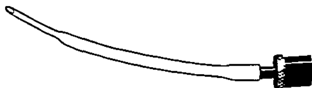


Fig 86 Cole tube

Length The length of oral endotracheal tubes can be measured approximately by taking the distance from the tip of the nose to the lobe of the ear and adding 1 to 2 cm to this measurement in infants, or 2 to 5 cm in older children The trachea being only 4 to 6 cm long invites inadvertent endobronchial intubation Infants are sometimes diaphragmatic breathers causing a slight descent and ascent of the bifurcation of the trachea with inspiration and expiration which further enhances the risk of endobronchial intubation

Nasal endotracheal tubes are somewhat longer than oral tubes For children from one to four years the length of the tube is taken as 1¼ times the distance from the tip of the nose to the lobe of the ear, from four to twelve years it is 1½ times the distance from nose to ear

For some time we have used a modification of the Foregger measure (Fig 87) for endotracheal tubes We prefer a metal gauge with a tapering slot down the center for measuring accurately the external diameter Along the right side is a scale in millimeters of varying external diameters of endotracheal tubes Opposite this is the average age for which that size is suitable For example a 4 6 mm (No 14 French) diameter tube is usually suitable for a newborn On the left side of the scale the length of the tube is measured in centimeters according to the age of the child These meas

urements of course, are not absolute for every patient, however, since the size of the larynx depends more on age than weight, it is surprising how closely the tube diameter can be approximated by this method

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Lubricant Lubricant for the tubes is very important in infants and children Our present practice is to use sterile Pontocaine (¼ per cent) jelly A fat-free, water-soluble base is used both to prevent the deterioration of the tube and to avoid the entrance of a lipoid into the lungs A small amount of the jelly, kept in stoppered collapsible tubes, is applied to the endotracheal tube just prior to insertion

The lubricant tends to allow maintenance of a much lighter plane of anesthesia and to reduce laryngospasm on extubation The argument that aspiration of foreign material is facilitated because the cords are left wide open following extubation is more theoretical than factual, since all protective *pharyngeal* reflexes are still active

Headrest A headrest is not essential but helps to elevate the head and keep it from rolling laterally The convenient doughnut shaped headrest designed by Waters is constructed of cotton waste wound tightly with a gauze bandage The outside is covered with oilcloth dipped in latex and a small washable slip cover encloses it when in use Miniature rubber tires with a cotton cover also have been used with good effect for this purpose

Bite Block The anesthesiologist should have some means of keeping the teeth apart following intubation This can be a tightly rolled plug of gauze with a long tape on it which can be strapped to the outside of the cheek preventing the gauze roll from falling into the pharynx A pharyngeal airway or a mouth gag serves the same purpose

Intubation Procedure

Visual Oral Intubation With all the endotracheal equipment ready at hand on a table the patient is anesthetized to the point of relaxation of the jaw muscles and obtundation of laryngeal and pharyngeal reflexes For skill dexterity, speed and gentleness it is convenient to follow a definite routine herein described for the benefit of the student

1 The headrest is placed under the patient s head

2 The endotracheal tube is lubricated (Fig 88) and placed on a clean towel to the right of the patient s head

3 The laryngoscope light is tested again and then the laryngoscope is grasped firmly by the handle in the left hand Better control of the laryngoscope can be obtained by holding the handle down near the blade

4 At the last moment the anesthetic mask is removed from the patient s face

5 The palm of the right hand presses backward on the forehead extending the head and neck

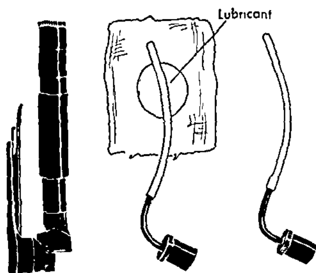


Fig 88 Endotracheal tubes with angle pieces lubricant and infant laryngoscope

6 The tip of the right middle finger opens the mouth and depresses the lower lip (Fig 89)

7 The laryngoscope blade is inserted into the right side of the patient s mouth (Fig 90) *with the handle of the laryngoscope first pointing toward*



Fig 89 Intubation Right middle finger opens mouth and depresses lower lip Head elevated on doughnut



Fig 90 Intubation Laryngoscope blade inserted in right side of baby s mouth, handle pointing toward patient s right shoulder Head elevated on "doughnut."

the patient s right shoulder since otherwise it may bump against the chest. After the blade is inserted into the mouth the handle can be swung around to the midline (Fig 91) The anesthesiologist holds his left elbow close to his side and his left hand on the laryngoscope lifts the lower jaw forward and upward If properly done, no pressure is exerted on the upper teeth or gum margin

8 The tip of the laryngoscope blade is advanced down along the right side of the tongue and lifts the tip of the epiglottis forward. A good exposure of the glottis is now obtained

9 The endotracheal tube is now picked up with the tips of the thumb and index finger of the right hand and the end of the tube is guided down into the glottis (Fig 92) The view of the glottis must be maintained during the insertion of the tube accomplished by looking down the laryngoscope and bringing the endotracheal tube in from the right side, down near the tip of the blade

At this point there is a slight variation from adult intubation, in order to insert the proper-sized tube it may be necessary to rotate the tube through 180 deg as it is being passed through the glottic opening

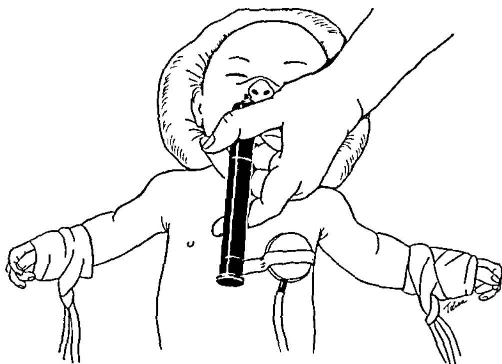


Fig 91 Intubation Laryngoscope handle swinging around to midline Head elevated on doughnut

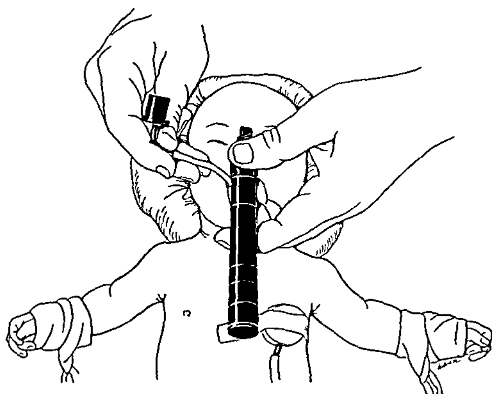


Fig 92 Intubation Insertion of endotracheal tube Head elevated on doughnut"



Fig 90 Intubation Laryngoscope blade inserted in right side of baby s mouth handle pointing toward patient s right shoulder Head elevated on doughnut"

the patient s right shoulder, since otherwise it may bump against the chest. After the blade is inserted into the mouth, the handle can be swung around to the midline (Fig 91) The anesthesiologist holds his left elbow close to his side, and his left hand on the laryngoscope lifts the lower jaw for ward and upward If properly done, no pressure is exerted on the upper teeth or gum margin

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Tactile Oral Intubation This method is used occasionally when a laryngoscope is not available The anesthesiologist stands at the left side of the patient He pulls out the tongue, passes the index and middle fingers of the left hand into the mouth and palpates the arytenoids and epiglottis The endotracheal tube is held in the right hand and is guided down the anterior surface of the left hand and fingers, thence forward into the glottic opening

Visual Nasal Intubation When the patient is sufficiently anesthetized so that the jaw is relaxed the well-lubricated tube is passed gently down along the floor of the nostril If the head is well extended, generally the tube will slip past this region without trauma The laryngoscope is then inserted into the mouth and the glottis exposed The endotracheal tube is pushed further through the nose and the tip of the tube guided toward the glottis The extreme tip of the tube is grasped in the Magill forceps and guided into the glottis As a rule, as large a tube can be passed nasally as orally, due to the distensibility of the side of the nose

Tactile Nasal Intubation This is very similar to the tactile oral method, with the advantage that the tube is being supported by the nose

Blind Nasal Intubation This procedure can be carried out in any age group It is immaterial which way the bevel faces Well-curved and well-lubricated tubes should be used As soon as the tube has passed the adenoid region the head is placed in the "sniffing" position and the anesthesiologist listens carefully to the breath sounds It is quite evident when the tube is in the glottic cup The tube may pass easily between the vocal cords however, it often impinges on one of the vocal cords

Although the intubation is completed there are one or two points which should be checked by the anesthesiologist Immediately following the insertion of the tube, the breathing often stops, especially in the infant One should gently compress either the chest or abdomen once or twice and listen for the breath sounds passing in and out of the tube With this assurance, the lungs can be inflated with oxygen from an anesthetic machine The anesthesiologist should listen to the breath sounds in the anterior part of the thorax If breath sounds are absent on the upper right side of the chest or over the left chest or if the right side of the thorax shows early and greater expansion than the left, it is strong evidence of right sided endobronchial intubation Rarely does an overly long endotracheal tube enter the left bronchus When the endotracheal tube is in place we strap it to the face with two pieces of adhesive, the middle part

10 The laryngoscope is removed gently from the mouth A wise precaution is to hold the endotracheal tube in place with the right hand while this is being done

11 The connector of the endotracheal tube is attached to the anesthetic apparatus and the lungs inflated with oxygen immediately

12 The bite block is placed between the teeth

13 The head is taken off the headrest and the headrest placed under the patient s shoulders

14 The tube is strapped to the face with adhesive (Fig 93)

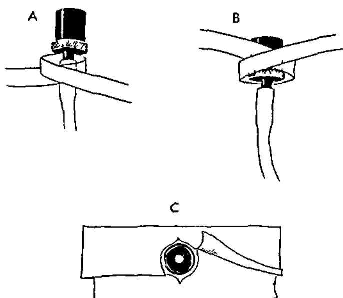


Fig 93 Endotracheal tube strapped in place with adhesive made fast to face (*A*) Adhesive around tube and connector (*B*) adhesive around connector (*C*) wide adhesive encircles connector for prone brain positions

When using a Macintosh laryngoscope a different procedure is followed The laryngoscope blade is inserted in the middle of the mouth and the tip of the blade is pushed firmly into the base of the tongue superior to the epiglottis This causes the epiglottis to rotate anteriorly so that the glottis comes into view In infants because the hyoid and thyroid bones are fused and the epiglottis is small and is angled more posteriorly we use a straight blade employing the same technic as described for a Macintosh laryngoscope

Some anesthesiologists intubate awake newborn infants or patients with partial respiratory obstruction This is considered safe, since spontaneous respiration is maintained

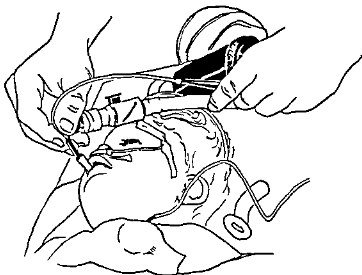


Fig 95 Endotracheal suction through connector port during or at end of anesthesia

Fig 96 Lateral Trendelenburg position with large suction tip available at close of anesthesia

of each passing around the endotracheal tube proximal or distal to the aspirating port

During operation on small infants where the hard palate is accessible, we hold a finger on it inside the mouth and extend the head This provides more direct alignment of the endotracheal tube and prevents its kinking or flattening by the acute curvature at the pharyngeal region which occurs when the head is flexed However, in operations where the endotracheal tube has to be moved frequently from one side of the mouth to the other, as in tonsillectomy adhesive strapping to the face is omitted

Extubation

The patient is extubated during either deep or light anesthesia, but when spontaneous respiration is present The pharynx and endotracheal tube are aspirated frequently with a soft rubber catheter (Figs 94 and 95)

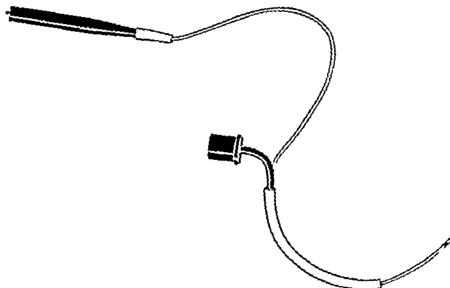


Fig 94 Endotracheal suction through connector port at close of anesthesia

and the lungs inflated with oxygen In deep anesthesia extubation, the endotracheal tube is removed an oropharyngeal airway inserted, and a mask and bag with high oxygen concentration applied to the face Should any indication of vomiting occur, the patient is placed in the lateral Trendelenburg position for gravity drainage (Fig 96)

Severe laryngospasm with alarming cyanosis sometimes follows extubation Sustained laryngospasm can be avoided by extubating the patient during extremely light anesthesia since in this condition the respiratory

INSUFFLATION TECHNIC

Insufflation another technic notable chiefly for its simple apparatus, is still favored by many, for its advantages include a marked reduction of dead space efficient carbon dioxide elimination, and prevention of body temperature elevation Nevertheless, when not contraindicated, the more efficient endotracheal methods which provide better control of pulmonary ventilation are largely replacing the insufflation technic in most pediatric centers

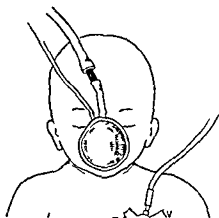


Fig 97 Open drop ether with oxygen flowing into nipple on mask A nasogastric tube is in place

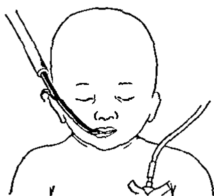


Fig 98 Oropharyngeal insufflation with mouth hook

The principle of this technic is the maintenance of anesthesia by insufflation of anesthetic vapors mixed with air or oxygen into the mouth or pharynx Oropharyngeal insufflation is performed by means of a metal mouth hook in the corner of the mouth (Fig 98) through an oropharyngeal airway nipple or through a rubber catheter sewn to the tongue Nasopharyngeal insufflation utilizes one or two tubes inserted through the nasal orifices (Fig 99) and placed in the pharynx The technic depends upon large flows of air oxygen or nitrous oxide-oxygen mixture blown

centers are not obtunded by the anesthetic agent The occurrence of severe laryngospasm also can be reduced by gentle extubation coincident with exhalation

OPEN DROP TECHNIC

The open drop technic is used chiefly for ethyl ether open drop anesthesia a tried and tested technic for use by the unskilled anesthesiologist, since in moderately deep planes it provides analgesia hypnosis, and relaxation and can be administered with simple and readily available equipment The technic itself properly administered, offers no resistance to respiration, but does cause slight increase in dead space and a small amount of carbon dioxide accumulation with consequent respiratory stimulation This increased respiration especially in light planes of anesthesia always provides the patient with adequate oxygenation if the airway is patent

In spite of these advantages there are disadvantages which are gradually sending the technic into oblivion in hospitals which specialize in pediatric anesthesiology Induction is usually very prolonged unpleasant, and interrupted by numerous bouts of breath holding particularly true in the infant under one year of age The nausea and vomiting occurring on emergence, while not so intense as in the adult patient, are still much more severe and prolonged than that observed after other anesthetic agents and the recovery period is generally prolonged Metabolic disturbances are quite marked especially as regards hepatic function, carbohydrate metabolism, acid base and fluid balance, consequently, ether may be a deleterious agent in the seriously ill, dehydrated child, especially one with severe myocardial hepatic, or renal disease

It is wise to premedicate children for open drop ether lightly so that respirations are not depressed Scopolamine or atropine alone is the premedication of choice in patients under five years of age, but is combined with the barbiturates in children beyond this age When there is a depression of respiration high concentrations of oxygen are administered under the mask (Fig 97) or the lungs are occasionally artificially ventilated with oxygen using a mask and bag

In infants, induction is often performed with ethyl ether ethyl chloride nitrous oxide or cyclopropane These agents of course, make the induction more pleasant and less psychically traumatic Stories, fairy tales, nursery rhymes, bright animated conversation toys and suitable music before and during induction are valuable psychotherapy

respiration Infants are given atropine or scopolamine only, while older children in addition are given pentobarbital (Nembutal) or secobarbital (Seconal), but no opiate drugs

Induction may be accomplished by open drop technic or ether vaporization directly from the copper kettle following nitrous oxide With the copper kettle the oxygen through ether flow, being very potent, must be increased in small 50 ml per minute increments to avoid laryngospasm

Maintenance of anesthesia with the copper kettle insufflation needs a low total flow of gases (2 to 3 liters per minute) with a moderate oxygen-through-ether flow Maintenance with the ether jar method of anesthesia, however demands a higher flow of 8 to 10 liters per minute to provide sufficient vapor concentration

Certain precautions are noteworthy in insufflation technic If nasopharyngeal catheters are used, care should be taken to place them just above the larynx and not further down into the esophagus By accidentally placing them in the esophagus, gastric distention will rapidly ensue The proper distance is approximately that from the tragus of the ear to the tip of the nose A sandbag under the shoulders and, if possible an oropharyngeal airway help to maintain a clear airway Protective ointment (boric acid 5 per cent) is usually placed in the eyes Aspiration of the pharynx is mandatory should blood or secretions begin to accumulate A 10 deg Trendelenburg position aids in preventing tracheal aspiration and laryngospasm Often insufflation technic may be highly improved if a thorough local anesthetization of the throat is performed

T-TUBE TECHNIC (AYRE'S T-TUBE)

A T-tube or Y-tube is a straight connector inserted into an endotracheal system with a sidearm open to the air The T-tube lies between the delivery tube from the gas machine and the endotracheal tube connector On inhalation the patient draws a large amount of air through the open arm of the T-tube and some gases from the anesthetic machine On exhalation the exhaled gases pass out into the atmosphere through the open arm of the T-tube (Fig 100) Artificial inflation of the lungs can be carried out by intermittent closure of the open arm of the T-tube by the anesthesiologist s finger

The apparatus has minimal resistance to breathing no moving parts, provides excellent carbon dioxide elimination, and furnishes a more stable gas composition than the open drop technic It is however wasteful of

over or bubbled through a liquid volatile anesthetic agent A trap bottle inserted between the ether container and patient helps prevent liquid ether from entering the trachea, but this method is crude in its control and it is difficult to develop enough ether concentration unless a warm water jacket is used around the vaporizer It also does not eliminate the danger of blowing liquid ether into the patient

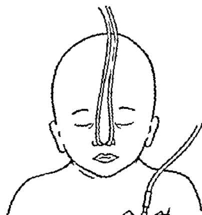


Fig 99 Nasopharyngeal insufflation through two nasal catheters

The newer type of vaporizer, the copper kettle is a vast improvement The high specific heat of the copper kettle provides a high and steady concentration of ether vapor, while the fine dispersion of the oxygen stream through the ether, created by passing oxygen through a porous disk, ensures maximal vaporization efficiency The vapor concentration delivered to the patient may be gradually but steadily increased by raising the oxygen flow through the ether and lowering the total flow of other gases In our experience this method provides the most efficient insufflation

The disadvantages of insufflation are major, inasmuch as even the skilled anesthesiologist has difficulty in maintaining an unobstructed air way and the unskilled inadvertently may allow partial obstruction throughout anesthesia Deep planes of anesthesia are necessary for the patient to tolerate the irritating ether vapor without laryngeal reflexes being aroused even after deep anesthesia is established it may be difficult to maintain since suctioning removes ether vapor from the throat and the progressively cooling vaporizer delivers less ether vapor Irritating anesthetic agents are widely disseminated throughout the room and are unpleasant, both for surgeon and anesthesiologist Furthermore, the lack of a reservoir bag prevents proper and positive immediate control of respiration

Premedication for insufflation technic is light since, assisted respiration not being possible, the patient must retain adequate spontaneous

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The apparatus has minimal resistance to breathing no moving parts, provides excellent carbon dioxide elimination, and furnishes a more stable gas composition than the open drop technic It is, however, wasteful of

gases necessitating a high flow of 8 liters or more per minute, and it floods the air with unpleasant explosive gases Respiration is not as readily controllable as with closed or semiclosed methods

The standard premedication is suitable with this technic

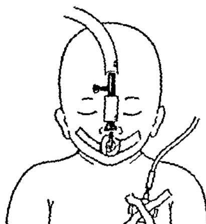


Fig 100 Ayre s T tube endotracheal technic

Any method of induction of ether anesthesia suitable for the infant or child may be used, the endotracheal tube inserted, and the T-tube and delivery tube from the machine connected to the endotracheal tube adapter Anesthesia is maintained with a high flow of oxygen and ether or nitrous oxide oxygen and ether, the flow being 8 to 14 liters per minute in infants and children These gases should be humidified

Delicate control of the pressure used during inflation is achieved by inserting another T-tube in the gas feed line with its open arm connected to a manometer This measures the pressure used when the arm of the regular T-tube is closed by the finger for inflation Usually a pressure of 10 to 20 cm of water is used such a pressure preventing rupture of pulmonary alveoli and pneumothorax, a real danger with this technic

As the technic tends to reduce body temperature, young infants should be placed on a warm water mattress in a warm room

Difficulty in maintaining older children at the necessary depth of anesthesia because of dilution of the anesthetic gas stream with air from the sidearm may be overcome by the addition of a few inches of rubber tubing on the sidearm This is not effective dead space since the high gas flow keeps this tubing filled with fresh gases at all times As an alternative, the anesthesiologist may supplement the inhalation anesthesia with intravenous administration of small doses of thiobarbiturates

NONREBREATHING VALVULAR TECHNIC

The valvular technic utilizes a double valvular arrangement which permits the inhalation of fresh gases and vapors from a breathing bag (Fig 101) or reservoir (Fig 102), while the exhaled gases are blown free into the atmosphere

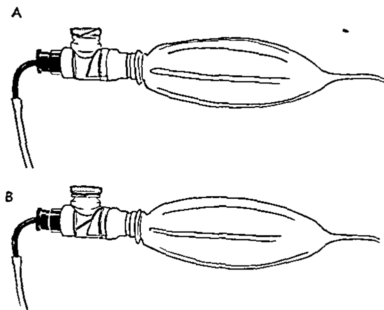


Fig 101 Nonrebreathing valvular technic with reservoir bag *(A)* Exhalation *(B)* inhalation

The more widely used nonrebreathing valvular technic consists of a plastic or metallic cylinder containing two unidirectional valves attached to a 2 5 liter reservoir bag The valvular apparatus is connected to a face mask or endotracheal tube During inhalation, the one-way inhalation valve opens, and anesthetic gases and oxygen are drawn from the reservoir bag at which time the exhalation valve is closed preventing dilution of the anesthetic mixture by atmospheric air On exhalation, the inhalation valve closes and the expired gases pass through the exhalation valve into the atmosphere The breathing bag is kept partially full with a 4 to 5 liter per minute flow of oxygen and nitrous oxide fortified with ether cyclopropane trichlorethylene or Fluothane

Older models of nonrebreathing valves (Leigh and Stephen Slater) have been replaced by the Fink (Figs 103 and 104) and the Lewis Leigh (Fig 105) nonrebreathing valves which can be used with spontaneous respiration or with assisted or controlled respiration Both of these valves

gases, necessitating a high flow of 8 liters or more per minute, and it floods the air with unpleasant explosive gases Respiration is not as readily controllable as with closed or semiclosed methods

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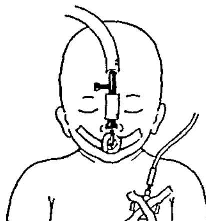


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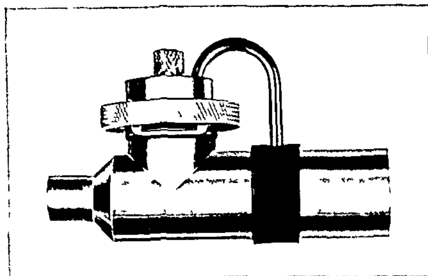


Fig 104 Fink valve showing detail

Fig 105 Lewis Leigh valve showing detail

controllable, uniform gas mixture and a method of assisting or controlling respiration

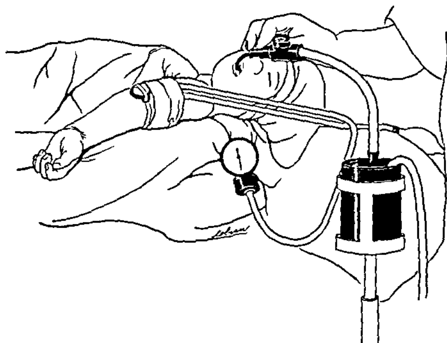


Fig. 102 Nonrebreathing valvular technic with Flagg can reservoir

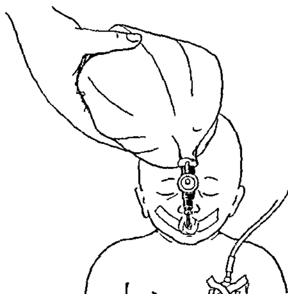


Fig 103 Heidbrink Fink non rebreathing valvular endotracheal technic for assisted or controlled respiration

are superior to former unidirectional valves, since one hand by compression of the breathing bag (Fig 106) opens the inhalation valve and closes the exhalation valve Release of the pressure on the bag closes the inhalation valve and opens the exhalation valve

With competent valves the nonrebreathing of exhaled gases prevents carbon dioxide accumulation and hypoxia The bag reservoir provides a

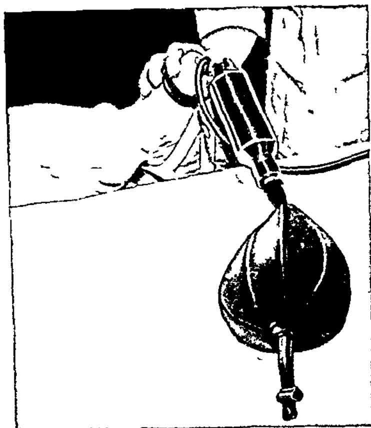


Fig 107 To and fro absorption in three year-old child

Since the soda lime canister is so closely contiguous to the patient s air passages, special care must be observed in preparing the canister When filled it must be gently agitated to pack down the soda lime and then completely filled to the top and the dust must be removed by blowing forcibly through the canister in both directions This aids in preventing lime dust from entering and irritating the respiratory passages

With the to and fro mask technic a headband is of aid in keeping a close fit of the mask on the face The canister rests on a large soft pillow with the bag hanging free over the end of the pillow The patient s head should be turned to one side In infants this method may be used as a semiclosed system with excess gases escaping from the partially opened tail end of the bag

The advantages of to and fro technic are low resistance to respiration due to lack of valves and long tubing more efficient absorption of carbon dioxide with the gas passing twice over the absorbent sensitive control of the anesthetic depth and simple rugged apparatus

Disadvantages are mainly mechanical in that it is difficult to maintain a closed system Others include carbon dioxide accumulation if the an

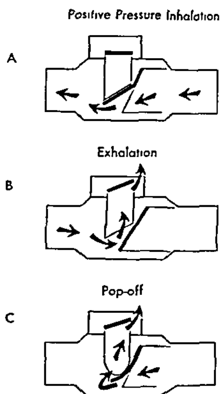


Fig 106 Lewis Leigh valve (*A*) Closure of exhalation chimney by inhalation valve on compression of breathing bag (*B*) release of pressure on breathing bag with escape of gases through exhalation valve (*C*) one-quarter turn of chimney piece to relieve overdistention of breathing bag

ABSORPTION TECHNIC

To and Fro

The earliest of carbon dioxide absorption technics, first utilized by Waters the to and fro absorption technic is a simple method applicable to infants and children The patient breathes back and forth through a canister of soda lime or Baralyme into a bag fresh gases being delivered near the face mask (Fig 107) or endotracheal tube (Fig 108) by an inlet nipple on the canister elbow

It is impossible for the soda lime canister to be exactly the size of the patient s tidal volume since this varies from breath to breath The absorbent *canister must therefore be as large as or larger than the patient s* greatest tidal volume We frequently use medium canisters (7 x 12 cm with a capacity of 350 gm) for infants and children recalling however that the proximal area of the soda lime will be exhausted first and the canister must be changed end for end or replaced with a new one about every half hour

Because of the relatively closed system the infant s body temperature tends to rise with this technic therefore the temperature must be monitored and the child cooled if necessary

air by passing it through Baralyme or soda lime is the same as in the to and fro technic, but here the gases flow in a circuit by means of inhalation and exhalation breathing tubes, the gas flow being directed by unidirectional inhalation and exhalation valves A bag reservoir with an inlet for fresh gases nearby completes the circuit

Most anesthesiologists find the circle filter system more convenient than other technics Providing easy control of ventilation and fairly accurate control of anesthetic mixtures, it is economical and has less tendency to increase the temperature However, there is added resistance from valves and tubing, the mixture is not changed as rapidly nor as often as is desirable and there are many more places for leaks to develop in the system

Present adult circle filter apparatus while often used for children, is unsuitable in its unmodified form, especially in a closed system The dead space is large for a child, since the valves, being at the distal end of the breathing tubes, allow reflux from the exhaled breath into the inhalation tubing before sufficient compression of the air column in that tubing closes the inhalation valve On the next breath, the patient inhales a portion of the gaseous mixture that he has just exhaled Another disadvantage is the considerable resistance in adult circle filter, 5 to 8 mm Hg, due to the relatively heavy stiff valves and turbulence in the tubing, as well as the soda lime resistance, this total resistance is too great for infants and young children Some of these objections can be overcome by placing light valves of low resistance in a plastic valve housing at the patient end of the breathing tubes where their function can be observed thus reducing the dead space markedly (assuming competency of the valves is maintained) and eliminating a large portion of the resistance

However, lag in changing the anesthetic mixture still remains, but two devices attempting to eliminate this situation are now available The Foregger-Adriani pediatric conversion kit (Fig 109) consists of a narrow bypass tubing from the bag to the mask fitted with a rubber bulb hand pump equipped with unidirectional valves by which means fresh gases are pumped from the bag to the mask almost constantly The more recent Edison (Roswell Park) circulator is similar with a slightly larger hand bulb pump and visible double unidirectional valves flushing fresh gases from the bag to the mask But both are somewhat laborious to pump continuously and occupy one hand of the anesthesiologist constantly

Until the simple circulator devised by Revell which automatically circulates the gases around the adult circle filter at a rate which allows

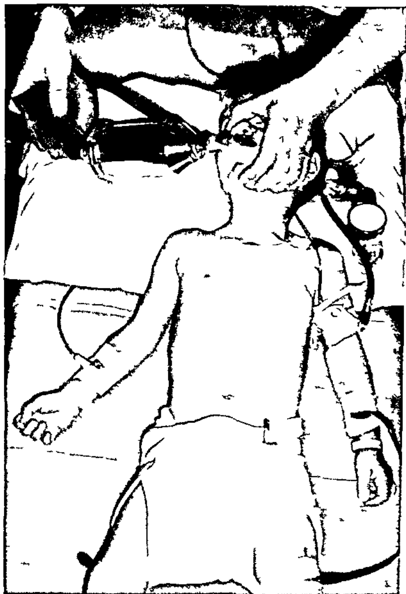


Fig 108 To and fro absorption technic with endotracheal tube

esthesiologist ignores the fact that the proximal soda lime portion becomes exhausted early unless he reverses the canister or replaces it about every half hour Finally rebreathing of hot gases is a constant invitation to hyperthermia

In Circuit

The circle filter or absorption in circuit technic first devised and used by Brian Sword, has become the main inhalation technic of anesthesia on this continent The principle of absorption of carbon dioxide from exhaled

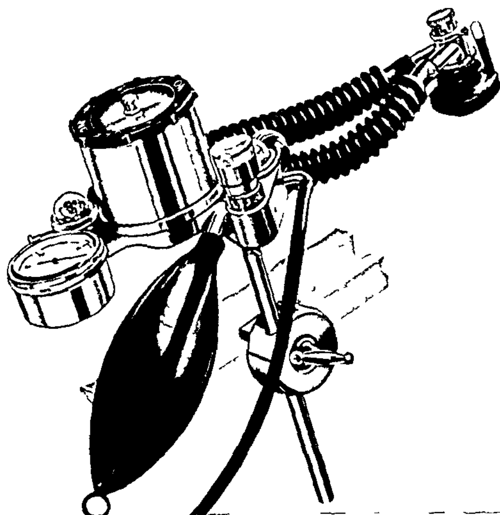


Fig 110 Heidbrink infant circle filter

in housings adjacent to, and on either side of, the soda lime canister Two small short, corrugated rubber breathing tubes connect from these to the face piece while another corrugated rubber tube connects the breathing bag to an inlet just proximal to the exhalation valve A manometer in the system measures the positive pressure when the bag is compressed or distended

Although a vast improvement on the adult circle apparatus for infants and children this system has several drawbacks The valves being back near the soda lime canister instead of near the face piece, do not entirely prevent reflux into the inhalation tube with consequent increase in dead space although the reduced bore and length of the breathing tubes reduces this somewhat If the soda lime canister is not filled carefully lime

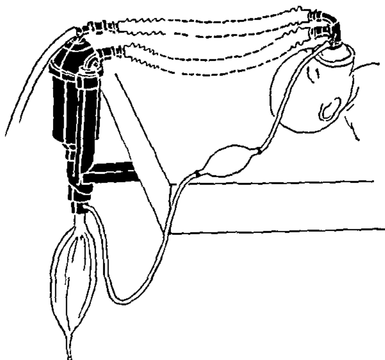


Fig 109 Foregger Adriani pediatric conversion kit

fresh gases to be inhaled with each breath of the infant or child is available *it is our opinion that the present infant circle filters are a better* answer to the problem of circle absorption in infants and children

Four types are, or have been in recent use The Foregger-Adriani pediatric conversion kit mentioned above is an attempt to adapt an adult circle filter for use in children Besides the circulator bypass described above which brings fresh gases from the bag to the mask, other features *are noteworthy The Y chimney fitting at the mask is replaced by an ob*turator with two tubes, one inside the other The inner tube channels fresh gases from the inhalation tubing to the patient while the outer tube carries away exhaled gases The large adult size reservoir bag is replaced by a 1 5 liter bag connected as usual below the soda lime canister The apparatus is a great improvement on the unmodified adult circuit filters, however, the double channeled chimney piece, while it reduces, does not eliminate excess dead space Also, as has been mentioned previously the labor of pumping the hard rubber hand bulb is a tiresome procedure

The Heidbrink infant circle filter (Fig 110) clamps to the operating table and has a small soda lime canister with the delivery tube from the gas machine attached to a nipple near the soda lime just distal to the inhalation valve Two disk-lift type inhalation and exhalation valves are set

With all these infant circle filters it is our custom to use a semiclosed technic with a total flow of 1 to 2 liters per minute, and to assist or control respiration in most instances, tending to reduce any remaining resistance and diminish the effort of breathing

We frequently intubate infants and small children to further reduce dead space and to prevent gastric distention occurring with controlled or assisted ventilation when the mask is employed Should distention occur while using a mask, a gastric tube is passed to remove the gas and to relieve any embarrassment of respiration

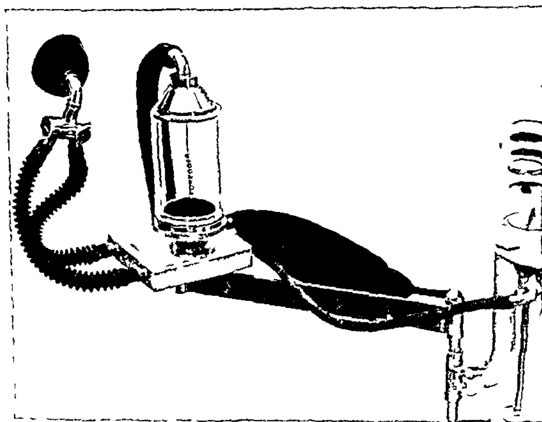


Fig 112 Foregger Bloomquist infant circle filter

INTRAVENOUS ANESTHESIA

In the conscious child, a slow subcutaneous injection of procaine over the vein, using a 26-gauge needle permits painless insertion of a styletted intravenous needle The difficulties of intravenous anesthesia in children can be overcome by dilatation of the veins and control of the patient with cyclopropane anesthesia In many of the infants a cut-down is in place, and small doses of the barbiturates can be injected slowly Intravenous

dust in the base where the central screw inserts will prevent a tight fit and cause a leak around the rubber gasket on top of the canister and the exhalation valve is difficult to adjust

The older type Foregger infant circle filter devised by Leigh (Fig 111) consists of visible, double unidirectional valves near the patient's face attached to two short, small bore breathing tubes which lead back to a horizontal soda lime canister At one end of the canister a bag and the delivery tube are placed in the circuit, with the advantage of eliminating backlash if the valves are kept competent However, its disadvantages are channeling of gases across the top of the soda lime if the canister is not tightly packed, and awkwardness of positioning the apparatus due to lack of a firm base

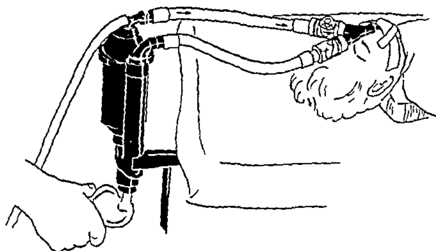


Fig 111 Foregger infant circle filter with upright canisters and visible double unidirectional valves

The fourth and best infant circle filter (Foregger-Bloomquist) (Fig 112) is a modification of the older type Foregger, utilizing the concept of an upright canister which forces the gas to pass through the soda lime without channeling and positioning of visible unidirectional valves near the patient The infant circle filter has been made practical by placing the upright canister in a square aluminum block with channels through it Anteriorly these channels attach to the two short breathing tubes leading to a unidirectional low resistance Y-valve and the patient, posteriorly, the channels accomodate a 1 5 liter bag with attached gas delivery tube on one side and a pressure gauge and exhalation valve on the other The aluminum block rests firmly on a jointed metal arm which swings in an arc from the gas machine and can be used in many positions

TOPICAL ANESTHESIA

Topical anesthesia consists of local anesthetization of mucous membrane, either as the total anesthetic for some diagnostic or surgical procedure, or more frequently in children, as part of a combined anesthetic technic The anesthetic agent is applied either as a water-soluble jelly, a cream, or spray, but the amount should be limited to reduce toxicity and therefore a fine nebulizer is desirable in smaller children Ointment is used on all endotracheal tubes to help reduce laryngeal spasm on extubation Although of dubious benefit in this regard, it does provide the necessary lubrication Analgesic ointments are sometimes useful in cystoscopy if an infant particularly a female is too debilitated to tolerate general anesthesia safely and cystoscopy must be done By coating the cystoscope with Pontocaine jelly or Xylocaine jelly, the examination can ordinarily be accomplished with little or no distress to the infant

Topical spray is particularly advantageous in supplying local anesthesia to the pharynx, larynx and upper trachea for certain surgical procedures and may be fortified by swabs held in the piriform fossae This form of anesthesia is very helpful either alone or in combination with light general anesthesia in providing analgesia and proper operating conditions for laryngoscopy removal of laryngeal papilloma, bronchoscopy, and bronchograms as it eliminates any tendency to laryngeal spasm and 'bucking while still maintaining adequate respirations and movement of the vocal cords Laryngeal and tracheal anesthetization is also very useful as an adjunct to general anesthesia for intraocular and intracranial operations where even slight coughing may cause exudation of the ocular contents or herniation of brain tissue In these cases where topical spray is necessary our drugs of preference are tetracaine hydrochloride (Pontocaine) 0 5 per cent and lidocaine (Xylocaine) 2 per cent with the dose of Pontocaine kept below 1 5 mg per kg and Xylocaine below 15 mg per kg of body weight

INFILTRATION ANESTHESIA

A tedious rather unsatisfactory method of anesthesia except for local excision of small superficial areas of tissue local infiltration is however used occasionally in moribund or very feeble infants and in children when general anesthesia appears to be highly dangerous Our drugs of choice are Procaine or Xylocaine but in dilute solutions using 0 25 per cent for infants and 0 5 per cent for older children Usually no vasoconstrictor

barbiturates have a limited application in infants, since their normal low blood pressure may be further depressed by the barbiturates

LOCAL ANESTHESIA

Anesthesia with local agents involves such methods of administration as topical, infiltration, nerve block, spinal, and epidural Widely used on adults these technics have never become as popular in infants and children but are practical and beneficial when modified to suit the varying needs of small patients

Since children are fearful of the unknown and do not hesitate to express this fear, they usually must be anesthetized lightly during administration of local anesthetic and the subsequent period of surgery Somnolence may be accomplished with heavy premedication, inhalation of nitrous oxide or cyclopropane, or by intravenous or rectal barbiturates In premedicating for local anesthesia one may use larger than standard dosages, generally of a barbiturate, opiate, and scopolamine If, on arrival in the operating room, the child is too wakeful we frequently give slowly an additional dose of 2 per cent thiobarbiturate, 6 per cent pentobarbital (Nembutal), 1 per cent meperidine (Demerol), or 0 3 per cent morphine solution intravenously This additional intravenous sedative is preferable to unduly heavy sedation on the ward, where patients are not observed continuously and may become dangerously depressed

One other modification must be made in using local anesthetic agents in infants and young children, the dosage must be reduced in accordance with the size of the patient to prevent toxic reactions These toxic reactions may be due to too large a dose of the drug given in a short time inadvertent intravascular injection of the correct dose or too rapid absorption *of a normal dose*

The reactions are of two types the more common type being an excitement phase leading to convulsions best treated with oxygen and intravenous barbiturates until controlled They may also be controlled momentarily with cyclopropane until venipuncture is accomplished A more serious reaction is a sudden collapse of the circulation demanding immediate treatment with oxygen, Trendelenburg position and intravenous circulatory support

With careful attention to dosage and with the customary mandatory precautions such as immediately available oxygen by mask intravenous barbiturates and analeptics ready in syringes, conduction anesthesia may be safely given to infants and children by experienced anesthesiologists

SPINAL ANESTHESIA

Spinal anesthesia, which has gained such popularity for adult patients, has never become widespread among pediatric patients Even today, it is used mainly in children seven years of age or older However, it can be used with benefit and safety in infants and young children for some operations if handled with knowledge and skill by those who have wide experience in spinal technic in older children

For acute appendicitis or toxic patients with peritonitis it is an excellent method when skillfully given, for it does not increase the existing metabolic acidosis as some inhalation technics will do However, now that hypothermia is used in conjunction with less toxic inhalation agents in these very ill, febrile patients, a general anesthetic may be given to them with very little disturbance of metabolic functions, practically obviating the need for using spinal anesthesia in the very young

Among the disadvantages of spinal anesthesia in infants and young children is the relative limitation of bowel constriction under spinal as compared with that in adults As with other forms of local anesthesia, children do not tolerate being awake under spinal anesthesia, and the vast majority must be kept somnolent either with heavy premedication nitrous oxide, or intravenous barbiturates The premedicant dosage of barbiturates (Seconal or Nembutal) and meperidine (Demerol) is usually larger than normal prior to spinal anesthesia, but the usual dosage of scopolamine is given Cardiac action respiration, and blood pressure are all monitored before and during the operation

The child, unless very sleepy, is usually given inhalation or intravenous anesthesia by a second anesthesiologist during the spinal puncture and thereafter kept asleep during the operation by the same method Adequate oxygen given by mask during the entire procedure ensures a reserve supply in the lungs and blood should respiratory depression or circulatory collapse occur

All the recognized spinal anesthetic drugs for adults may be used for children in doses which correspond proportionately to their height and weight including procaine, Pontocaine Xylocaine and dibucaine hydrochloride (Nupercaine) Vasoconstrictor drugs may also be added to the local anesthetic drug in the same proportion as for adult anesthesia to reduce its dosage and prolong its effect

The use of a prophylactic sympathomimetic drug before spinal anesthesia in children is a matter of opinion Most children have an excellent

is added, as it may cause local tissue sloughing in debilitated children and the total amount of solution used at one time must be measured carefully to prevent overdosage Nevertheless, it must always be remembered that concentration and the addition of a vasoconstrictor or a spreading agent, as well as total dosage, are important factors governing the amount of drug used

NERVE BLOCK ANESTHESIA

While nerve blocks do not have wide application unless combined with supplemental anesthesia, certain plastic operations on the fingers and toes can be done with a nerve block quite satisfactorily in very young infants Often no additional anesthesia is required in these patients, however, children beyond a few months of age are apt to be restless This may be controlled either by meperidine (Demerol) or barbiturates given intravenously, or by nitrous oxide analgesia Although it might be argued that nitrous oxide analgesia alone may be adequate, this is not the case in most instances unless the concentration of nitrous oxide is such that some degree of hypoxia also exists

Certain blocks, however, have some degree of popularity and usefulness These are the supraorbital and supratrochlear blocks for lacerations of the forehead, infraorbital and mental blocks for some facial lacerations, maxillary and inferior dental blocks on older children for dental extractions, cervical blocks occasionally used for removal of glands but seldom otherwise in children since thyroid disease is rare, brachial plexus blocks for open reduction of fractures of the upper limb, or for plastic repair of tendons or nerves of the forearm, wrist blocks for plastic operations on the hand, metacarpal blocks for finger operations, intercostal and paravertebral blocks, seldom used, abdominal wall blocks, occasionally in combination with other technics field blocks occasionally for herniorraphy or appendectomy, sciatic nerve blocks and metatarsal blocks occasionally stellate and lumbar sympathetic blocks to improve the circulation in the upper or lower extremities

For nerve blocks we use procaine or Xylocaine but favor the latter for its spreading quality rapid onset and lasting effect Concentrations used are 0 5 per cent for sympathetic nerve blocks 1 per cent for most other nerves and plexuses, and 2 per cent on older children for large nerve trunks such as brachial and sciatic plexuses A vasoconstrictor may be added for slower absorption and prolonged effect and we often use epinephrine 1 200,000 for this purpose

SPINAL ANESTHESIA

Spinal anesthesia which has gained such popularity for adult patients has never become widespread among pediatric patients Even today, it is used mainly in children seven years of age or older However, it can be used with benefit and safety in infants and young children for some operations if handled with knowledge and skill by those who have wide experience in spinal technic in older children

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The use of a prophylactic sympathomimetic drug before spinal anesthesia in children is a matter of opinion Most children have an excellent

cardiovascular system and active sympathetic nervous system which compensate quickly for minor falls in blood pressure, and do not need peripheral vascular support if the spinal level is no higher than D6 However, a styletted needle should always be inserted into a vein to have a ready port available for rapid therapeutic parenteral administration if necessary Common vasopressor drugs are methoxamine hydrochloride (Vasoxyl) and phenylephrine hydrochloride (Neo-synephrine) If used, these drugs are given proportionate to the weight of the child

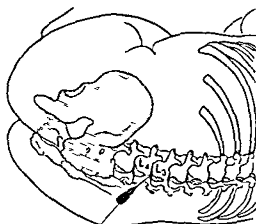


Fig 113 Diagram of spinal needle in skeleton of two year-old child

The care of the patient following the injection of the anesthetic solution into the subarachnoid space is still the most important part of the spinal anesthesia Just as all anesthetic drugs can be used so can all the different technics The only variation in equipment is the decrease in length of the spinal needles the shorter ones being used for infants and small children The spinal puncture is done easily in infants and children since the spinal column is flexible and the spinous processes can be separated widely In infants the puncture is made below the third lumbar vertebra to avoid injury to the spinal cord which may reach this level The injection is usually made with the patient in the lateral flexed position as in the adult (Fig 113)

Continuous spinal anesthesia has become almost obsolete with the advent of the more prolonged single-dose type achieved by the mixture of vasoconstrictors with spinal anesthetic drugs It will therefore, not be discussed here

EPIDURAL ANESTHESIA

The two common routes of administration of local anesthetic agents into the epidural or extradural space are caudal (Fig 114) and lumbar both have been used with good effect in many children The technic in both instances is essentially the same as for adults, with the exceptions that shorter needles must be used according to the size and age of the child and the children must usually be kept anesthetized during the puncture and the operation

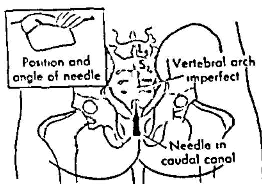


Fig 114 Diagram of needle in caudal canal of infant

Drugs and concentrations are the same as for adults, but the total dosage must be reduced in accordance with the weight of the patient Commonly employed drugs are procaine or Xylocaine, 1 or 2 per cent solution with or without epinephrine 1 200 000 As in adults, care must be taken in the initial puncture not to pierce the dura and to inject the drug into the subarachnoid space

The usual precautions of immediately available oxygen under pressure a styletted needle in a vein and prepared vasopressors must be observed, as well as keeping a careful record of pulse respiration, and blood pressure

HYPOTHERMIA

Hypothermia (lowering the body temperature) is used as an adjunct to anesthesia in order to avoid hypoxia and hypercarbia We have found it particularly valuable in two types of cases first, in congenital heart diseases namely tetralogy of Fallot tricuspid atresia, patent ductus arteriosus when there is a very large heart with a rapid pulse atrial septal defect, and pulmonary valvular stenosis and second in severely ill febrile or toxic infants and children

the body in ice water Sensations of extreme cold stimulate cutaneous proprioceptors which send impulses to the hypothalamus, producing heat retention by reflex generalized vasoconstriction and heat production by increased muscle tone and shivering During hypothermic anesthesia it is essential to control muscular activity in order to prevent increased oxygen consumption Deepening of anesthesia with cyclopropane provides such control

With hypothermic technic, the demand of the body for general inhalation anesthetic agent becomes markedly lessened, so that at temperatures below 29° C only very small amounts of anesthetic agent are needed to control respirations and ensure a quiet operative field Temperatures vary between 28° and 33° C, with the degree of desired temperature reduction depending upon the size of the child the electrocardiographic response of the heart to cold and the nature of the contemplated operative procedure

Allowances must be made for a further body temperature drop of 2° to 4° C after the patient is removed from the ice packing and placed on the operating room table

The rate of cooling depends upon the amount of adipose tissue and muscle mass Newborn infants cool very rapidly in view of their imperfect temperature regulation scanty subcutaneous fat, poor vasomotor control and inadequate shivering reactions

Once the deeper tissues are cooled, the patient's temperature remains at a low level with only slight variations over a period of one to two hours The blood pressure may be difficult to record by the usual means due to the coexisting hypotension and spasm of the large arteries induced by the cold Inasmuch as an inhalation anesthetic agent is administered in only minimal amounts, spontaneous respirations return when the temperature is between 27° and 30° C

Rewarming which is allowed to take place slowly is prolonged due to the peripheral vasoconstriction and sluggish circulation induced by hypothermia As soon as effective ventilation is displayed, the patient is extubated Small infants are placed in a warmed incubator where their temperatures are allowed to return to normal over an extended period of time During rewarming the effects of cold are reversed with a return of blood pressure pulse rate consciousness and occasionally shivering Postoperative oxygen is ordered for all patients operated upon for cyanotic heart disease The return of body temperature to normothermic levels takes from three to six hours after completion of the operation

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CHAPTER 14

ANESTHETIC EQUIPMENT

BASIC EQUIPMENT

Conscientious preparation of anesthetic equipment is one of the most important factors attributing to the safe management of the patient during the anesthesia An anesthetic machine equipped for the selected anesthetic agents and technic, a suction, and a variety of endotracheal tubes as outlined in the chapter on the subject of intubation are prepared Because of the wide range in the sizes of patients and the comparative briefness of some of the procedures done in infants and children, the pediatric anesthesiologist must keep ready for use a wide variety of easily accessible equipment Since we have found that the cabinet models of most anesthetic machines lack convenience, we have adopted the illustrated mobile cabinet which is equipped with our basic requirements (Figs 117, 118, 119, 120 and 121)

In addition to the above basic anesthetic equipment, there are two classes of equipment, namely cardiac monitors and ventilators which are playing an increasingly important role in pediatric anesthesiology

CARDIAC MONITORS

In modern pediatric anesthesiology with its artificial metering of the oxygen employment of a host of new anesthetic agents and technics, and use of assisted or controlled breathing, the indication of acute hypoxia or overdosage of anesthetic agent, at times is detected only by an abrupt depression of the cardiovascular system Therefore continuous monitoring of the heart is absolutely necessary for the safe conduct of the anesthesia

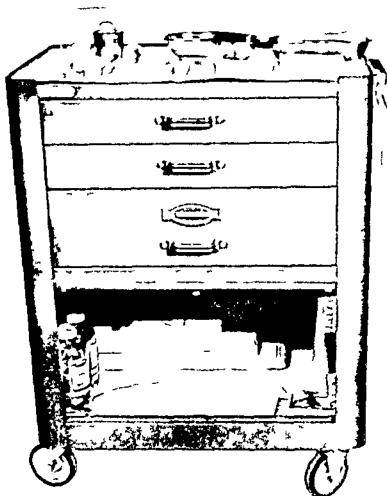


Fig 117 Mobile anesthesia cart for individual anesthesiologist

Precordial Stethoscope

The use of the precordial stethoscope is the simplest method of monitoring the changes in the intensity of the sounds, rate, and rhythm of the heart The monoaural plastic ear mold connected to the chest piece by standard intravenous tubing (Fig 122) is used on every anesthetized patient in our hospital unless there is a special reason precluding its use Nevertheless loosening of the adhesive which holds the chest piece in place accidental disconnection of the stethoscope tubing or conditions making the use of the precordial stethoscope impossible necessitate the employment of additional methods of continuous monitoring of the cardiovascular system For these reasons, and also as a source of corroborating evidence of cardiovascular changes, the following methods of monitoring the heart are used in pediatric anesthesiology

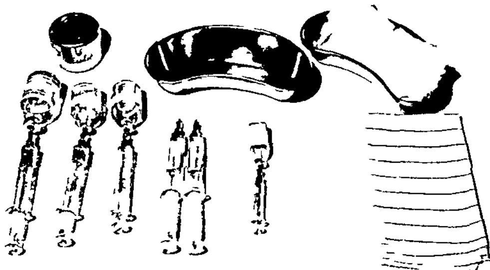


Fig 118 Anesthesia cart (top surface)—showing drugs and supplies

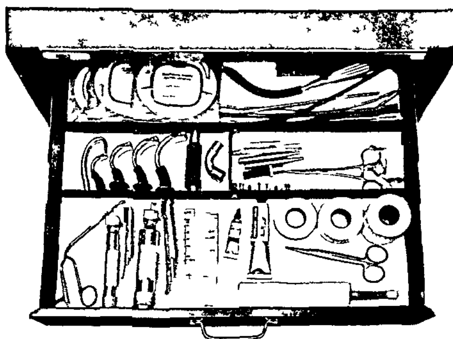


Fig 119 Anesthesia cart—top drawer contents



Fig 120 Anesthesia cart—second drawer contents

Esophageal Stethoscope

In instances where a precordial stethoscope is impractical, such as anterior chest wall burns and some intrathoracic operations an esophageal stethoscope is used to monitor the heart The apparatus consists of a large rubber urethral catheter with the holes in the distal end covered by a sleeve of Penrose drain (Fig 123) Proximally, the catheter connects to the ear mold by a short length of plastic tubing The catheter is passed either through the nose or mouth and advanced in the esophagus to the point where the heart sounds are heard best

Plethysmograph

An acute depression of the cardiovascular system generally is detectable through a drop in blood pressure The determination of systolic blood pressure in infants is accomplished by either the auscultatory, oscillatory, or flush (capillary refill) method The oscillatory method is rapid, convenient, and reliable if the inflatable bladder is the proper size for the

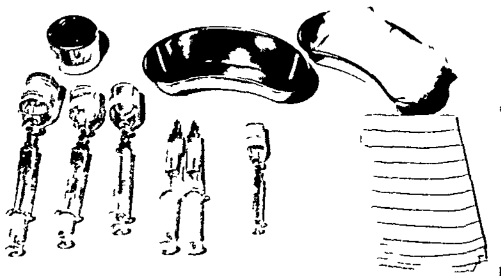


Fig 118 Anesthesia cart (top surface)—showing drugs and supplies

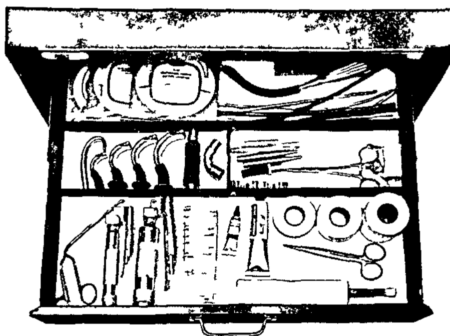


Fig 119 Anesthesia cart—top drawer contents

Fig 123 Esophageal stethoscope (*A*) Ear mold (*B*) esophageal portion

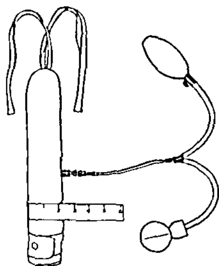


Fig 124 Infant blood pressure cuff (A H Robins Company Inc Richmond Virginia)

disappearance of a flashing light or the sound of a beeper confirms cardiovascular depression and immediate action may be lifesaving (Figs 125 and 127)

Fig 121 Anesthesia cart—bottom drawer contents

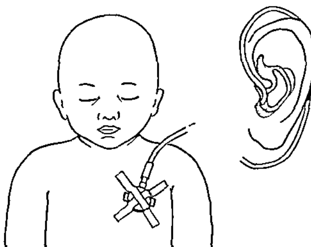


Fig 122 Ploss monoaural steth oscope with plastic ear mold

patient and completely encircles the arm (Fig 124) A plethysmograph attached to a finger or a toe a method applicable to most patients affords a continuous method of detecting a depression of the blood pressure The

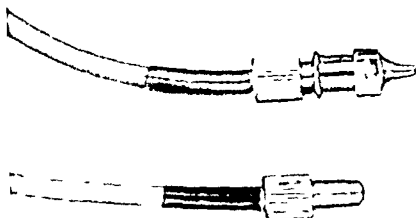


Fig 126 Needle electrodes for electrocardiograph

Carbon Dioxide Analyzer

The determination of the alveolar carbon dioxide concentration by the Liston Becker rapid infrared absorption analyzer (Fig 128) is valuable as a monitor of the pulmonary capillary blood flow, and hence cardiac hemodynamics With adequate uniform pulmonary ventilation and diffusion alveolar carbon dioxide tension declines abruptly when pulmonary blood flow falls below a critical point such as occurs with overdosage of anesthetic agent severe shock interruption of circulation (Fig 129) cardiac arrest ventricular fibrillation ineffective cardiac massage (Fig 130) or manipulation of the heart (Fig 131) Upon restoration of efficient pulmonary circulation there is an immediate increase in alveolar carbon dioxide tension With hypothermia there is also a depression of the alveolar carbon dioxide tension (Fig 132), which may be related either to decrease in metabolism or to depression of the circulation

Electroencephalograph

The electroencephalograph may be used to monitor severe hypoxia or depth of anesthesia Brain waves are the measurable expression of the electrical activity of the brain substance and may be used to monitor the depth of anesthesia as well as evaluate the effectiveness of cerebral blood flow

Typically slowing of the frequency followed by a straight line electro-

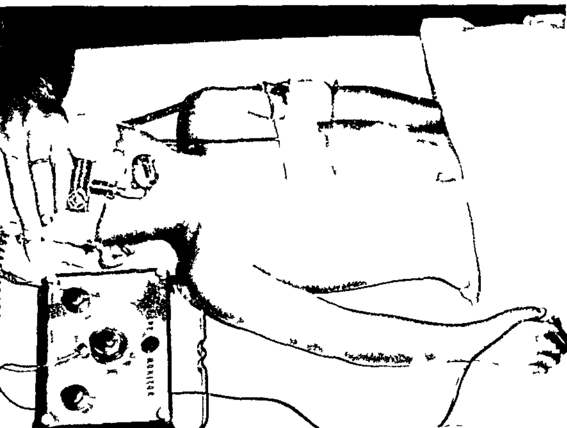


Fig 125 Allen heart monitor Plethysmograph on patient's finger

Electrocardiograph

Information concerning the nature of cardiac rate and arrhythmias during anesthesia is achieved by the electrocardiograph which may be visualized on a cathode ray oscilloscope Needle (Fig 126) or surface electrodes may be used The electrocardiograph is valuable in cases of poor risk patients with weakened hearts hypothermia intrathoracic surgery and operations involving manipulation of intracardiac catheters

The chief deficiency of the electrocardiograph is that it does not record the degree of cardiovascular depression It is, however the only assured means of distinguishing between a sinus tachycardia and that very serious cardiovascular complication—ventricular tachycardia

There are other monitors of simple construction which partially portray the electrical potential of the heart, record the heart rate, and detect a depression of blood pressure (Fig 127)

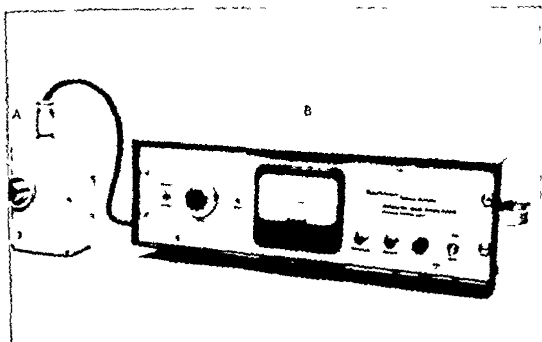


Fig 128 Liston-Becker rapid infrared CO_2 analyzer (A) Pick up unit (B) amplifier and recorder dial

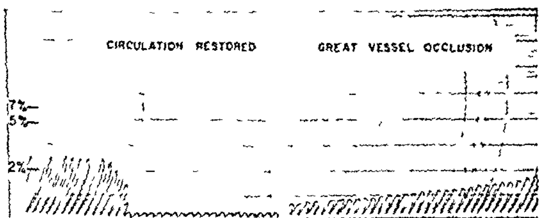


Fig 129 CO_2 continuous tracing taken through port of endotracheal tube in hypothermic patient Reading tracing *right to left* decreasing CO_2 is shown during occlusion of superior and inferior venae cavae pulmonary artery and aorta abrupt return of CO_2 is shown with restoration of circulation when the clamps are removed

tern will occur in reverse order, slow activity appearing first, followed by faster activity until the maintenance pattern is re established

When discussing the subject of monitoring the heart, one should not overlook one of the very best methods which occurs on those rare occasions in the course of cardiac surgery when an opportunity is afforded to visualize the heart At such times, changes in rate, rhythm size, and



Fig 127 This finger plethysmograph monitors the pulsations of the arteries in the finger It is also used to determine systolic pressure (E & J Manufacturing Co Burbank California)

encephalogram is the most characteristic change associated with hypoxia or deep anesthesia (Fig 133) If hypoxia is corrected or the anesthesia lightened, recovery of the electroencephalogram to the maintenance pat-

HYPOTHERMIA

36° 35°

34° 33°

7% 5% 2%

Fig 132 Alveolar CO_2 continuous tracing showing decreased CO_2 with fall in body temperature

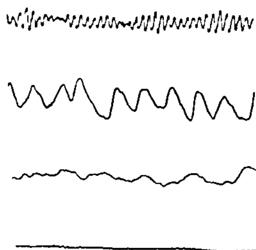


Fig 133 Electroencephalographic tracing showing from above down increasing depth of anesthesia

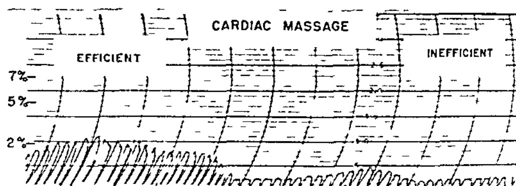


Fig 130 Reading *right to left* alveolar CO_2 continuous tracing during cardiac massage for ventricular fibrillation in hypothermic patient

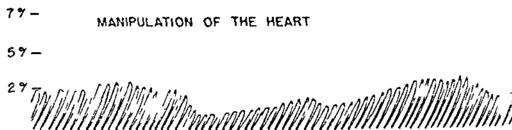


Fig 131 Continuous tracing of alveolar CO_2 in hypothermic patient There is depression of CO_2 when the heart is lifted out of the pericardium demonstrating a reduced pulmonary blood flow

color of the heart combined with the surgeon s estimation of the cardiac tonicity provide the best evidence of cardiovascular changes

VENTILATORS

The extensive use in pediatric anesthesia of sedative preanesthetic medication respiratory-depressing anesthetic agents and muscle relaxants has made it obligatory to do some form of manually or mechanically assisted or controlled breathing in order to avoid hypoventilation When using assisted or controlled respiration endotracheal technic will reduce dead space and prevent distention of the stomach but the small endotracheal tube and connector obstruct the inspiratory and expiratory flow rate even when the widest bore connector and tube are used and high pressures applied to the breathing bag

sure, ordinarily, cannot be attained with manual control of respiration

Secondly, the frequency of respiration should be somewhere close to the normal respiratory rate for that patient The most frequent error in artificial ventilation of the lungs in pediatric anesthesia is hypoventilation, detected by the gradual onset of tachycardia or arrhythmia

Thirdly an occurrence of pallor may indicate hypoxia from hypoventilation or may also be due to a sustained high positive pressure phase which occludes pulmonary capillary blood flow, but should be distinguished from the pallor of hyperventilation

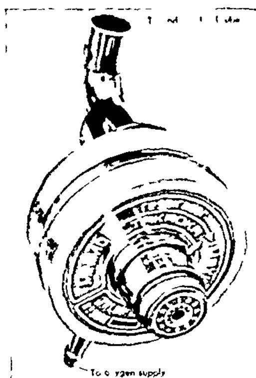


Fig 135 Takaoka ventilator

The rapid, infrared, continuous recording, alveolar carbon dioxide analyzer, in which the microcatheter is inserted in the endotracheal tube, is an excellent monitor of pulmonary ventilation as well as a monitor of the cardiovascular system A rise in alveolar carbon dioxide tension usually means hypoventilation an exhausted carbon dioxide absorbent, or rebreathing, a fall in alveolar carbon dioxide tension may mean hyperventilation although extreme hypoventilation would give a low carbon dioxide tension but obviously this would not be alveolar sampling

The anesthesiologist must not be confused by the theoretical terms of volume-cycled, pressure cycled or time cycled ventilators His only reliable guides have been emphasized above Examples of ventilators are illustrated in Figures 134 135, and 156 (p 315)

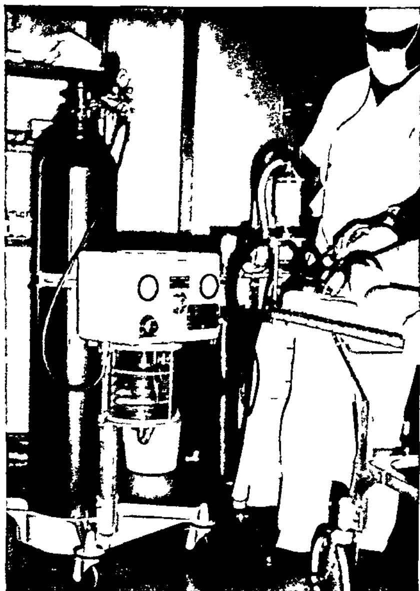


Fig 134 Bennett ventilator attached to Bloomquist infant circle filter

The anesthesiologist when using a ventilator cannot rely upon either the manufacturer s instructions or upon a nomogram, but must rely on clinical signs Of prime importance is careful observation of the degree of expansion of the chest or lungs on inspiration The degree of expansion of the thorax must be at least equal to that seen in normal breathing Because of the narrowed endotracheal tubes and connectors used in infants, adequate expansion may be achieved only with high positive pressures The slight negative phase not only will greatly assist the venous return of the blood to the heart but also will increase the flow of gases through the narrow endotracheal tubes and connectors during expiration Negative pres-

SECTION

III

PREANESTHETIC MEDICATION AND PREPARATION

Because of the extreme lability of the pediatric patient, it is essential that the diagnosis history physical examination laboratory results, and x rays be evaluated and the pertinent information recorded on the anesthetic chart (Figs 136 and 137) by the anesthesiologist at the time of the preanesthetic visit Additional specific information can be obtained from the attending pediatrician or surgeon The surgeon must outline his plan relative to maintenance of fluid and electrolyte balance, probable blood loss duration of surgery, required muscular relaxation patient position and the possible use of electro cautery x rays, or vasoconstrictors

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PREVIOUS SURGICAL AND ANESTHESIA HISTORY

ELECTROLYTES Cl

BLOOD PRESSURE
HEART DISEASE
CONGESTIVE FAILURE

HEMOGLOBIN

PERITONITIS
LIVER DISEASE

STEROID THERAPY

ENCEPHALOPATHY

SUMMARY OF POSITIVE FINDINGS

COMPLICATION

HEMORRHAGE

VOMITING
OBSTRUCTION

OTHER

TEMP | OD | 1 | 2 | 3 | 4 | 5 | 6 | 7
PULSE

POSTOPERATIVE REMARKS

POSTOPERATIVE COMPLICATION (Code

DEATH Code

Fig 137 Back of duplicate of anesthetic punch-card record retained for statistical analysis by anesthesia department

to plan his anesthetic management, including besides the choice of anesthetic agents and technics a careful plan for the avoidance of tracheal aspiration of vomitus, precautions against hypotension, and the physical conditions necessary for the contemplated procedure

SITE OF OPERATION

CHILDRENS HOSPITAL
OF LOS ANGELES
ANESTHESIA RECORD

IDENTITY CHECKED
CONSENT CHECKED

DATE ___ AGE ___ YRS ___ MO'S ___ DAYS ___ WEIGHT ___ LBS
DIAGNOSIS
OPERATION
HBG ___ GMS URINE ___ T ___ P ___ R ___ ANES TIME
C TIME

PREMEDICATION — TIME — BARB — OPIATE — BELLADON — EFFECT

INDUCTION

REMARKS

C CLO
BARB
ETHER

FLUIDS
5% D
NS
BLOOD

POSITION

FINAL CONDITION

TOT L

ANESTHESIOLOGISTS
ANESTHETIC METHODS
SURGEONS
OPERATION
FORM REVISED

ENDOTRACHEAL
EASY DIFFICULT
ROUTE
DIAMETER MM
LENGTH CM
PACK OR CUFF

PREM. — N.B. — 1-3M — 4-7M — 8-11M — 1-2Y — 3-7Y — 8-12Y — 13+

AGENTS — METHODS — ENDOTRACH — ANES COMPLIC — O S

Fig 136 Pediatric anesthesia record—official hospital record

A thorough perusal of available information should be followed by the preanesthetic visit to the patient wherein essential physical findings are confirmed and patient confidence is established

By this time, the anesthesiologist usually has sufficient information

To achieve the desired conditions a combination of drugs is generally employed, among them being the opiates the antihistaminics, the barbiturates or tribromoethanol combined with an anticholinergic drug of the belladonna group

Among the advantages of opiate or opiate like drugs are their ability to produce a quiet cooperative but not comatose, patient and their production of analgesia during and following the anesthesia Disadvantages are chiefly respiratory depression and nausea however the latter can be ameliorated in children by scopolamine and barbiturates and, in some instances, almost eliminated by antihistaminics Of the narcotics in common usage morphine meperidine (Demerol) and codeine are the most prominent Although usually administered by the intramuscular or subcutaneous route one half to one hour preoperatively if a more rapid result is desired, they may be given slowly by the intravenous route

The narcotics particularly meperidine have been noted to have an effect in children dissimilar to that seen in the adult Even with large amounts of drug hypotension is seldom seen, indeed hypertension and tachycardia are the common cardiovascular effects observed and marked respiratory depression is an infrequent occurrence Narcotics are analgesics Unfortunately the more analgesic narcotics produce greater respiratory depression Nausea can occur upon the patient assuming the upright position but is controllable with antinauseants Narcotics make the patient wakeful but cooperative Following or just prior to induction of anesthesia we frequently administer 1 mg per kg of body weight of meperidine intravenously to supplement analgesia in nonexplosive technics The narcotic antagonists n allylnormorphine hydrochloride (Nalline) or levallorphan tartrate (Lorfan) may be resorted to in the rare instances when depression of respiration is persistent

The barbiturates most frequently employed in premedication are secobarbital (Seconal) pentobarbital (Nembutal), thiopental (Pentothal), or thiamylal (Surital) Administration is either oral as an elixir or capsule or rectal by means of a suppository or solution The rectal route however is extremely unreliable both from the standpoint of absorption and of administration Furthermore the usual agents administered per rectum frequently prolong unconsciousness postoperatively

The technic of rectal administration of preanesthetic solutions consists of the insertion of a No 12 French catheter 4 or 5 in into the rectum (Fig 139) It is not necessary to provide a cleansing enema prior to the rectal instillation of small quantities of anesthetic solution In fact, an

CHAPTER 15

PREANESTHETIC MEDICATION

The subject of preanesthetic medication is a controversial one and has enthusiastic proponents of all dosage schedules, varying from the very light to the more profound While each institution usually has a basic guide of drugs and dosages for each age group, such a guide frequently is found to be incomplete, therefore, a detailed satisfactory preanesthetic medication table should be evolved, with the understanding that many factors may modify this basic schedule Our basic pattern of premedication is shown in Figure 138

Age	*Weight*	*Pentobarbital or Secobarbital*	*Morphine*	*Meperidine*	*Scopolamine or Atropine*
0–1 year	3–21 lb				0 1 mg
1–2	30	30 mg	1 mg	10 mg	0 15
2–3	34	45	1	15	0 15
3–4	38	45	1 5	20	0 2
4–5	44	60	2	25	0 2
5–6	50	60	3	30	0 2
6–8	55	60	4	35	0 3
8–9	60	75	5	40	0 3
9–10	65	75	6	45	0 3
10–11	74	90	6	50	0 3
11–12	80	90	6	50	0 4

Fig 138 Premedication guide for infants and children

histaminics have been widely used their main advantage being in the field of nausea therapy While of use in all patients antihistaminics are of particular value in burned children where it is extremely important that appetite and fluid retention be regained rapidly following each graft or dressing procedure In addition the antihistaminic agents find continuing value in those cases where the patient presents allergic symptoms These agents are generally administered intramuscularly or rectally

Scopolamine or atropine is given either subcutaneously or intramuscularly at the same time as the opiate but if atropine alone is used it is ordinarily administered approximately one half hour prior to the administration of anesthesia In our pediatric experience scopolamine is the prime inhibitor of secretory activity and atropine is the agent most effective in inhibiting other reflex parasympathetic activity With large dosages of atropine bradycardia with either succinylcholine or cyclopropane anesthesia is seldom observed There are side effects to these belladonna drugs They inhibit sweating may cause hyperthermia (which can be controlled), dilate the bronchi gastrointestinal tract and bladder, and scopolamine makes the patient forgetful

As with any routine many conditions may modify preanesthetic medication Age weight physical condition specific disease conditions, the operation contemplated and the method of anesthesia may all be factors of consideration Infants during the first year of life are usually given only atropine or scopolamine however infants during the first two or three days of life rarely need any drying agent at all since at that time there is virtually no respiratory tract secretion

Patients overweight underweight with high intracranial pressure, or with cardiac disease require only one quarter to three quarters of the routine sedation Mentally disturbed, deaf or hyperthyroid patients require increased sedation

In infants and children open drop ether is best performed if the premedication consists of either atropine or scopolamine alone On the other hand such anesthesia as nitrous oxide is best supported by relatively heavy analgesic supplement in the preanesthetic medication The importance of *planning* for the anesthetic agent and technic to be used cannot be overemphasized

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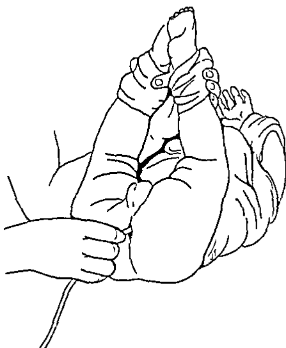


Fig 139 Insertion of lubricated catheter into the rectum of an infant for instillation of a barbiturate or tribromoethanol

enema just before surgery merely stimulates the bowel to evacuate its contents including recently instilled medication

Since the solution for rectal medication is preferably administered over a three- to five-minute period, the buttocks are strapped firmly together with adhesive tape (Fig 140) to prevent leakage, for the infant or young child possesses an extremely active lower bowel, and solutions so administered may be readily evacuated

In place of or in combination with, barbiturates or opiates, the anti

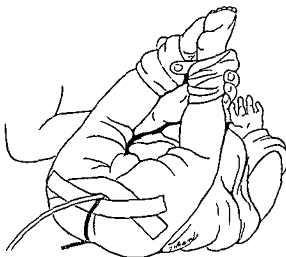


Fig 140 Firm strapping of the buttocks with adhesive tape helping to retain instilled anesthetic solution

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IMMEDIATE PREANESTHETIC MANAGEMENT

Preferably, the patient is brought in an appropriate conveyance to the induction room a short time prior to the scheduled surgery a premature or full term newborn under 3 5 kg is conveyed in an oxygen-enriched, humidified incubator heated to 32 2° C (90° F), an infant between 3 5 kg and 15 kg is brought in a carrier with quadralateral enclosure (Fig 141), an infant or child over 15 kg is conveyed on a mobile stretcher with a strap firmly across the hips

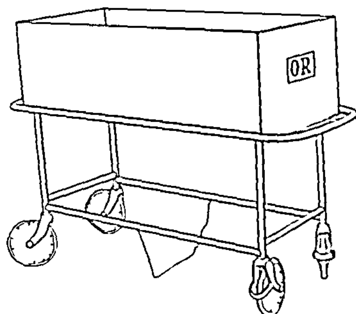


Fig 141 Quadralateral enclosure for safe transportation of infants and children

In the induction room, the patient comes under the charm of a kindly, soothing attendant, soft music and lively mobiles and murals No infant or child is ever left unattended

The anesthesiologist must indisputably confirm the identity of the patient from the chart from the wrist band on which is typed the patient s name or from the ward nurse or surgeon An older child may be able to confirm his name when asked

The oropharynx is examined carefully for broken missing or loose teeth and for foreign bodies Bruises or abrasions should be noted Written consent by the parents for anesthesia and operation and the type of operation scheduled should be checked from the notation of the surgeon on the chart

The efficiency of the lay-in or cut-down is assured by injecting rapidly,

CHAPTER 16

PREANESTHETIC PREPARATION

GASTRIC CONTENTS

Of extreme importance to the safety of the patient is the absence of solid food in the stomach during the anesthesia Since the stomach of the normal infant or child takes at least five hours to evacuate completely, no infant or child should be fed solids orally within six hours of the time of operation Except in case of dire emergency all pediatricians, surgeons and anesthesiologists should adhere to this rule of time Clear, sweetened fluid may be given orally to within two hours before anesthesia Oral fluids given later than this are apt to be vomited during induction

In cases of dire emergency there are two methods of avoiding the extremely perilous complication of aspiration of food into the lungs The stomach is aspirated or a large esophageal tube with inflatable cuff is passed into the stomach. The cuff is then inflated and the tube withdrawn slightly so that the inflated cuff occludes the space between the tube and the esophagus preventing the regurgitation of gastric contents around the tube As a further precaution all of these emergency cases should be intubated to assist the maintenance of a patent airway

TRANSFUSION AND CUT-DOWN

When significant blood loss may occur during surgery, the blood is typed cross matched and sufficient blood is ordered Before surgery in infants a cut-down is done in the saphenous vein at the ankle

In every case it is essential to establish before surgery proper hydration and electrolyte balance

SECTION

IV

ANESTHETIC MANAGEMENT of SURGICAL PROCEDURES

In presenting considerations of the anesthetic management of pediatric surgical procedures the authors appreciate that there are today myriads of ways of preparing and anesthetizing patients for any given operation The methods employed will vary from country to country and even from hospital to hospital within a country However, the objectives are always the same namely maximum safety and comfort for the patient and facility for the surgery To achieve these objectives the anesthesiologist requires an understanding of the patient s condition the proposed surgery the preparation of the patient, and the selection of anesthetic agents and technic All these features of

intravenously, 2 ml of normal saline, whereby any leaks or blockage will be detected and corrected In most instances a styletted needle is inserted into a vein (Fig 142) under either local or general anesthesia, and

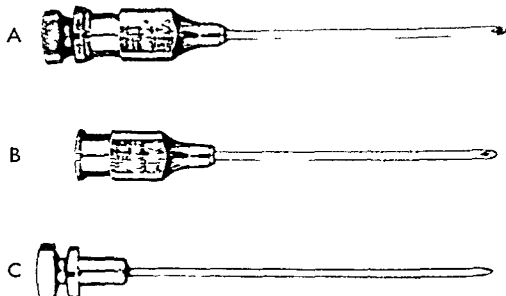


Fig 142 Styletted needle *(A)* Needle with stylet inserted *(B)* needle *(C)* stylet

strapped into place In major surgical cases two styletted needles may afford an extra portal of entry for blood should the blood loss be excessive or the one needle become dislodged

A blood pressure cuff of proper size is applied to the arm The maximal precordial impulse is palpated, and the precordial stethoscope is strapped over this place A plethysmograph is attached to the patient s finger (Fig 127 p 258) Blood pressure pulse rate and rhythm are noted and recorded regularly on the anesthesia chart while respiration is observed for rate rhythm and character

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SECTION

IV

ANESTHETIC MANAGEMENT of SURGICAL PROCEDURES

In presenting considerations of the anesthetic management of pediatric surgical procedures, the authors appreciate that there are today myriads of ways of preparing and anesthetizing patients for any given operation The methods employed will vary from country to country and even from hospital to hospital within a country However, the objectives are always the same, namely, maximum safety and comfort for the patient and facility for the surgery To achieve these objectives the anesthesiologist requires an understanding of the patient s condition the proposed surgery, the preparation of the patient and the selection of anesthetic agents and technic All these features of

the practice of pediatric anesthesiology have been discussed in a general way in the preceding chapters In this section of the book will be outlined the application of these features to the anesthetic management of specific principal operations performed on infants and children, following as closely as possible the system of classification employed in Section I (p 2)

CHAPTER 17

OPERATIONS ON THE BODY AS A WHOLE AND THE INTEGUMENTARY SYSTEM

INCISION AND DRAINAGE OF ABSCESSES AND CARBUNCLES, REMOVAL OF TOENAILS, SKIN GRAFTS, EXCISION OF SMALL LOCAL TUMORS, BIOPSIES, PLASTIC RECONSTRUCTION OF POLYDACTYLISM OR SYNDACTYLISM, SUTURING OF WOUNDS, AND REMOVAL OF DRAINS, DRESSINGS, OR PACKS

For most of the above-mentioned operations, infants and children require general anesthesia in order that the procedures may be performed under stable conditions In spite of the fact that these operations are sometimes termed as 'minor,' the customary meticulous anesthetic preparation must be observed

The preanesthetic medication is dependent largely upon whether the patient is to be immediately ambulatory or hospitalized following the procedure In either case one of the belladonna derivatives is given, since this provides decreased salivary and bronchial secretions, minimal cardiac vagal reflexes and early ambulation, but, if the patient is to be hospitalized opiates or barbiturates also are given

Cyclopropane or a combination of cyclopropane and nitrous oxide using either a nonrebreathing technic or infant or adult circle filter technic provides extremely rapid induction and recovery periods and is preferred for prolonged operations where blood loss is not a factor The cyclopropane dilates the veins and facilitates the insertion of a styletted needle through which fluids and other medications such as barbiturates or muscle

relaxants may be given at any time during the operation Older children who are hospitalized prefer the induction of anesthesia with an intravenous short acting thiobarbiturate This is followed by cyclopropane or a combination of nitrous oxide and cyclopropane

Several methods are available when nonexplosive, nonflammable conditions are desired nitrous oxide and Fluothane with the circle filter technic, a combination of 30 per cent oxygen, 40 per cent cyclopropane, and 30 per cent helium, employing the Hingson's portable anesthetic machine (Fig 143), a combination of nitrous oxide and trichlorethylene,

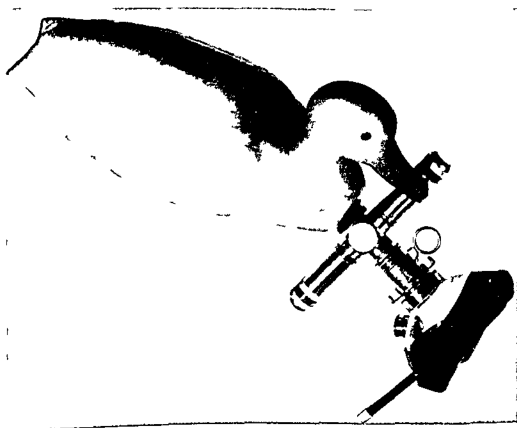


Fig 143 Hingson s readily portable anesthetic machine in which a combination of oxygen cyclopropane and helium is employed

using the nonrebreathing technic or trichlorethylene, using an inhaler which supplies metered amounts of trichlorethylene in air Endotracheal technic is used for prolonged operations and for operations in which the patient is in the lateral or prone position

Most of the patients who undergo any of the afore mentioned operations require only a brief period of postoperative care since they very early

eliminate the gaseous anesthetic agents, resume their diet, and are ambulatory

Classified under operations on the body as a whole are two usually extensive procedures—the surgical treatment of burns and the excision of sacrococcygeal teratomas—each of which requires a more detailed description of its anesthetic management

SURGICAL TREATMENT OF BURNS

The surgical treatment of extensive burns usually consists of early dressings, adequate debridement, and early skin grafting of the clean denuded areas to prevent the fatal loss of plasma and protein and to protect the wound from infection

In the evaluation of the patient, the anesthesiologist discusses with the surgeon the possibility of low blood volume, anemia, hypoproteinemia hemoconcentration myocarditis, septicemia, inanition vitamin deficiency, and degree of renal dysfunction, all of which reduce the myocardial reserve and make the patient a ready candidate for shock Other considerations of significance to the anesthesiologist are the treatment prior to surgery, the proposed surgical treatment, movement and positioning of the patient, the expected blood loss, the need of a cut down and in the instances when there is marked laryngeal and pharyngeal edema from a facial burn, the wisdom of performing a tracheostomy

The anesthesiologist on his preanesthetic visit gives reassurance to the child to mitigate the terror of the frequent visits to the operating room, for numerous operations are usually required in the treatment of burns He often discusses with the child the choice of anesthetic agent and technic Some children prefer an inhalation agent such as cyclopropane for induction while others prefer an intravenous thiobarbiturate For premedication in the acutely ill period, one-half the normal amount of meperidine (Demerol) with scopolamine is administered intramuscularly one hour before anesthesia To avoid nausea and to re-establish the normal dietary intake an antihistaminic is given at the same time either as a suppository or intramuscular injection

To relieve the pain from movement, the anesthesia is induced in the patient s bed in the operating room by mask and bag or by intravenous thiobarbiturate If there is no cut down, two large-bore styletted needles are inserted and taped in the splinted forearm or leg The dressings are removed and the child is moved gently onto a sterile sheet covering the operating room table If the prone position is required during the surgery,

the patient is intubated using a small dose of succinylcholine chloride Since the frequency of the operations magnifies the possibility of traumatic laryngitis, the endotracheal technic is used sparingly, but never omitted when it is necessary to maintain the patency of the airway

If an explosion proof dermatome is to be used, cyclopropane is preferred because it ordinarily does not depress the myocardium However, if a nonexplosion proof dermatome is to be used a combination of meperidine (Demerol) up to 2 mg/kg (1 mg/lb) of body weight nitrous oxide, and succinylcholine chloride is employed supplemented by minimal dosages of intravenous thiobarbiturates, minimal because of their myocardial depressant effect For burn dressings analgesia is sufficient, while for skin grafts, immobility also is necessary to prevent displacement of grafts

Certain specific safeguards concern the anesthesiologist in the operating room management of the burned patient These are monitoring and control of the body temperature, prevention of infection or the spread of infection, supportive treatment, and cardiac monitoring and stimulation

A warm operating room mitigates heat loss from large denuded areas, the room temperature being regulated in accordance with a continuous recording rectal or esophageal thermometer, on the other hand, in the septicemic burned child with an elevated temperature, a cool room of 18° C (64 4° F) is required

Extraordinary precaution must be exercised to prevent the large wound from becoming infected, which it does very easily In addition, if a burn is infected, spread of this infection to other cases must be avoided Therefore anesthesia personnel wear gowns and discard them in the operating room at the termination of the surgery The rules regarding the cleaning of equipment and the scrubbing of the anesthesiologist s hands before approaching another case must be strictly observed

Supportive therapy is nowhere more important than with burns Blood transfusion is necessary to replace blood loss on the operating table Anemia and hypoproteinemia due to blood vessel injury, infection, poor intake of food, and loss of blood during the debridement require correction with blood transfusion Blood is customarily pumped into the patient during debridement and skin grafting when rapid blood loss is being replaced (Fig 144) If the patient is intubated he can at this time be placed on the automatic ventilator On the other hand, when blood loss is small, the transfusion is given by means of a slow drip during change of dressings This meticulous care is essential due to the weakened condition of the myocardium, damaged by myocarditis, by malnutrition, or by



Fig 144 The vein in the left arm is cannulated for blood transfusion since during the debridement of a burn there is a tremendous blood loss

hyperkalemia and unable to withstand sudden overloading of the circulation which might precipitate cardiac failure Impending cardiac failure is gauged by a rise in venous pressure, visible in distention of the neck veins in the horizontal position, and a greater tendency for reflux of the blood into the intravenous fluid as the bottle is lowered toward the patient

If hemoconcentration is present, as seen with high hematocrit levels, 5 per cent glucose in water or plasma is used as a blood diluent Glucose will increase diuresis, provide calories, and prevent consequent hemoconcentration and thrombosis from dehydration Plasma when utilized, should

be cross-matched plasma from only one to four donors to reduce the risk of hepatitis

Because of the reduced cardiac reserve, another cardiac monitor in addition to the stethoscope is used Calcium gluconate, 10 per cent, using 0 5 to 1 ml (50 to 100 mg) after each 100 ml of blood is often used to increase the cardiac tone If the existing heart rate is slow, the increased slowing often produced by calcium is prevented by atropine, 0 06 mg (gr 1 1000), given intravenously prior to the calcium

Before the child leaves the operating room he is given an antihistaminic drug slowly by the intravenous route to relieve nausea and to promote early resumption of food intake postoperatively He is moved gently from the operating table to a clean bed or frame and placed on his side if possible Intravenous fluid therapy is continued if necessary He is returned to the postanesthetic recovery room Food by mouth is given as soon as tolerated by the patient Postanesthetic visits to the child will help him maintain a healthy mental and emotional attitude, thereby laying a foundation for a peaceful induction of anesthesia on subsequent occasions

EXCISION OF SACROCOCCYGEAL TERATOMAS

Surgery for excision of sacrococcygeal teratomas often is a prolonged and difficult dissection of a poorly defined large mass on one or both buttocks The anesthesiologist discusses with the surgeon the history and the extent of the lesion the positioning of the patient the estimated blood loss the amount of blood to be grouped and cross-matched, the arrangements for a cut-down in the upper limb, the use of cautery, and the general condition of the patient

If there is no general disability, the infant or child is given premedication according to the schedule set forth in Section III (p 268)

The choice of anesthetic agent and technic will depend chiefly upon the surgeon s plans For either prone or lithotomy position with use of cautery by the surgeon we employ endotracheal, nonexplosive technic A small intravenous dosage of succinylcholine chloride will facilitate intubation Following intubation the infant is positioned either in the prone position with sand pillows under the shoulders and hips, or in the lithotomy position Anesthesia can be maintained with a succinylcholine chloride drip and nitrous oxide inhalation or with any other nonexplosive technic When the patient is in the prone position artificial ventilation of the lungs should be carried on manually or with a mechanical ventilator, which en-

ables the anesthesiologist to have his hands free to pump in the blood if the loss is copious as the hemorrhage can be very brisk

After the dressing is applied the operating table is straightened out and the infant slowly placed on his back Breathing and consciousness soon return On account of the long duration of intubation the infant may need to be placed in cold moist atmosphere for a few hours The intravenous cut-down is left in place, since more blood may be required to replace that lost by postoperative oozing

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in circuit, to and fro or nonrebreathing technic For long operations (Fig 145) or when the patient is in the prone position, endotracheal anesthesia is employed to facilitate the ventilation of the lungs If muscle re-

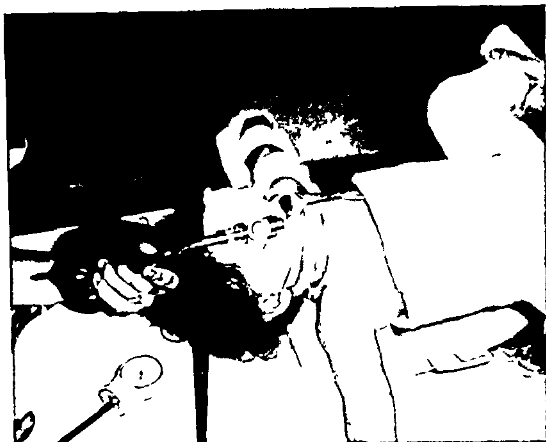


Fig 145 A patient with a plaster spica applied following correction of bilateral dislocated hips Endotracheal nonrebreathing valvular technic is employed

laxation is required intermittent succinylcholine chloride or the longer-acting muscle relaxants are given intravenously If the patient has been in the prone position during surgery, the change to the lateral position should be accomplished slowly to prevent hypotension either from the change in the position of the heart or from the pooling of blood in the extremities or abdominal viscera

SHORTENING AND LENGTHENING OF BONES, OPEN REDUCTIONS, ARTHROPLASTY, ARTHRODESIS, AND AMPUTATIONS

The anesthetic management for this group of more extensive operations on the musculoskeletal system is the same as for the less extensive ortho-

CHAPTER 18

OPERATIONS ON THE MUSCULOSKELETAL SYSTEM

REMOVAL OF A SCREW OR NAIL FROM THE BONE, APPLICATION OF KIRSCHNER WIRE TRACTION, LOCAL EXCISION OF BONE CYST, CLOSED REDUCTION OF FRACTURE, APPLICATION OF HIP SPICA, MANIPULATION OF A JOINT, CLOSED REDUCTION OF A DISLOCATION, DRAINAGE OF ABSCESS, REMOVAL OF FOREIGN BODY FROM THE MUSCLE, MYOTOMY OF THE STERNOCLEIDOMASTOID MUSCLE, TENOTOMY, TENOPLASTY, AND EXCISION OF GANGLION

The above procedures, as a rule, require analgesia alone or analgesia and muscle relaxation and entail minimal or no blood loss

If the procedure includes the application of a restraining appliance, it is advisable to warn the child of this fact before anesthesia Because many of the procedures in this category entail repeated disturbing operations with severe postoperative pain the child is given heavy premedication with meperidine (Demerol) oral or rectal barbiturate and scopolamine, but weak respiratory muscles or a long chronic illness necessitate marked reduction in dosage of depressant drugs

In a large number of these orthopedic operations, cautery and x ray are an integral part of the procedure, therefore nonexplosive anesthetic agents such as intravenous thiobarbiturates combined with either nitrous oxide and trichlorethylene or nitrous oxide and Fluothane are employed For many of the short operations a mask and bag are used with absorption

intubation difficult and render an awake intubation advisable after thorough spraying of the throat and cords with a local anesthetic With no distortion of head or neck the patient is induced slowly with a small amount of intravenous thiobarbiturate (Pentothal or Surital) followed by cyclopropane Two styletted needles are inserted in the upper limbs After intubation is accomplished the anesthesia is changed to a nonexplosive technic

The patient is then turned to the prone position and the blood pressure checked at once since occasionally the movement from supine to prone position may cause hypotension in chronically ill or bedridden children (Fig 146) Blood transfusion is started immediately through a cannu-

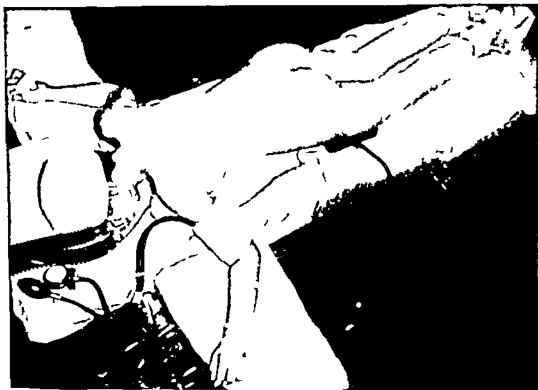


Fig 146 A patient postured for a spinal fusion Styletted needles are in both hands for transfusion during surgery Bolsters are placed under the shoulders to elevate the thorax and allow normal thoracic excursion

lated vein in the arm and throughout the procedure the anesthesiologist assists or controls the respiration to avoid a hypoventilation from the prone position or the reduced vital capacity

The patient should be extubated only after reflexes have returned On account of the duration of these operations and the pulmonary dysfunction,

pedic operations described in the first part of this chapter, but here there are the possible added hazards of decrease in cardiovascular and hepatic reserve, amyloidosis, renal impairment and calculi from chronic inactivity or infection, and a large blood loss If the surgeon anticipates a large blood loss during surgery then preparations are made to give blood during the operation

REDUCTION AND FIXATION OF FRACTURE OF THE MANDIBLE

Wiring of the upper and lower jaw may be a necessity in the operative repair of the fractured mandible In many cases it is debatable whether to rely on nasotracheal intubation or to request that a tracheostomy be performed prior to induction of anesthesia However, when a complete fixed occlusion of the mouth is anticipated, tracheostomy is the procedure of choice inasmuch as a clear airway can be maintained both operatively and postoperatively

Again the anesthetic agents and technics are the same as those used for the orthopedic operations described in the first part of this chapter

STERNOPLASTY

Endotracheal anesthesia is employed for sternoplasty to ensure adequate pulmonary ventilation since the removal of costal cartilages further diminishes the rigidity of the thorax Also a stomach tube should be kept in place during and after surgery to prevent gastric distention

Postoperatively some of the rigidity of the thorax is restored by a supporting frame which is wired to the sternum and keeps it elevated

SPINAL FUSION AND REDUCTION OF COMPRESSION FRACTURES OF THE SPINE

Some of the patients scheduled for spinal fusion or reduction of compression fracture of the spine have grave pulmonary dysfunction from severe kyphosis and scoliosis

With the lowered vital capacity preanesthetic sedation should be reduced Blood should be cross-matched beforehand, a blood pressure cuff applied on the arm or leg and a stethoscope placed over the precordium Some patients are operated on when they are in a body cast, and such a cast must be prepared so that it is instantly removable if cardiac massage is required Careful examination of the position of the head in the cast is necessary, since a lesion high in the thoracic or cervical region may make

intubation difficult and render an awake intubation advisable after thorough spraying of the throat and cords with a local anesthetic With no distortion of head or neck the patient is induced slowly with a small amount of intravenous thiobarbiturate (Pentothal or Surital) followed by cyclopropane Two styletted needles are inserted in the upper limbs After intubation is accomplished the anesthesia is changed to a nonexplosive technic

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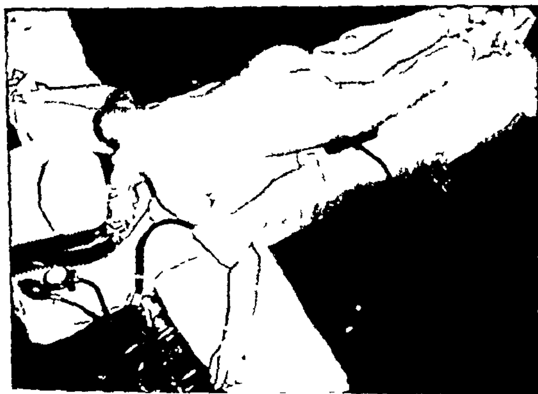


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The patient should be extubated only after reflexes have returned On account of the duration of these operations and the pulmonary dysfunction,

the patient should be put in cold, moist atmosphere for a few hours post operatively to minimize any subglottic edema resulting from prolonged intubation

FASCIAL TRANSPLANT FOR WEAK ABDOMINAL MUSCLES

This operation is an attempt to compensate for paresis of abdominal muscles following poliomyelitis In an effort to stabilize the thoracic cage, fascia lata straps are transferred from the thigh, the lower ends being rotated upward and attached under the skin to the recti or lower ribs Most of these patients have pulmonary dysfunction with decreased tidal volume and vital capacity Long immobilization in bed, together with the effects of viral myocarditis, reduces their cardiovascular reserve, while kidney function also may be impaired

In the preanesthetic medication, sedatives should be omitted, since they may depress the child s weak respiration to the extent of causing hypoxia and hypercarbia

Two methods of anesthesia are satisfactory for such patients By employing controlled respiration with a cuirass type of chest respirator, analyzing the alveolar air with a carbon dioxide analyzer and regulating the respirator accordingly, proper ventilation and anesthesia may be maintained analgesia is all that is necessary and it can be accomplished with small amounts of cyclopropane It is unwise to use an endotracheal tube, for these children are susceptible to pulmonary infections postoperatively and are unable to overcome subglottic edema from intubation should it occur

The alternative technic is circle or to and fro absorption with a mask, *permitting the patient to breathe on his own with slight assistance to com* pensate for any depression of respiration or resistance in the apparatus, but one must guard against gastric distention, visible in the left upper quadrant, since it is very easy to inflate the stomach of these patients For supportive therapy an intravenous drip of 5 per cent glucose in water is used

At the end of the surgery while the patient is still anesthetized the trachea is aspirated to remove any secretions because these children lack an effective cough, their main defense is rapid removal of all anesthetic agents so they can be fully conscious soon after the termination of surgery Further aspiration of the trachea is performed postoperatively as required Intermittent positive pressure breathing treatment three or four times daily is also recommended

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CHAPTER 19

OPERATIONS ON THE RESPIRATORY SYSTEM

OPERATIONS ON THE NOSE AND ACCESSORY SINUSES

Removal of Polyps and Tumors, Submucous Resection, Turbinectomy, Rhinoplasty, Maxillary, Frontal, and Ethmoidal Sinus Operations

For these operations, usually performed on older children our standard preanesthetic medication according to the age and weight of the patient is given

There are three principal considerations in the management of the anesthesia for these operations (1) endotracheal anesthesia is used to remove the anesthesiologist from the operative field and to prevent blood from entering the trachea Since these operations are generally performed on older children a cuffed oral endotracheal tube is used (2) nonflammable and nonexplosive anesthetic agents are employed, for the surgeon often uses cautery, and (3) anesthetic agents such as trichlorethylene and Fluothane, which may cause ventricular fibrillation with epinephrine or any vasopressor with a catechol nucleus are not used if the surgeon controls bleeding with these vasopressors

Bearing in mind these considerations anesthesia is induced with intravenous thiobarbiturate, the patient is intubated orally with the aid of muscle relaxant and anesthesia is maintained with nitrous oxide and increments of muscle relaxant using nonrebreathing or absorption in cir

cuit technic with manually (Fig 147) or mechanically controlled respiration

The anesthesiologist should have the child almost awake with complete restoration of the muscles of respiration at the end of surgery since the

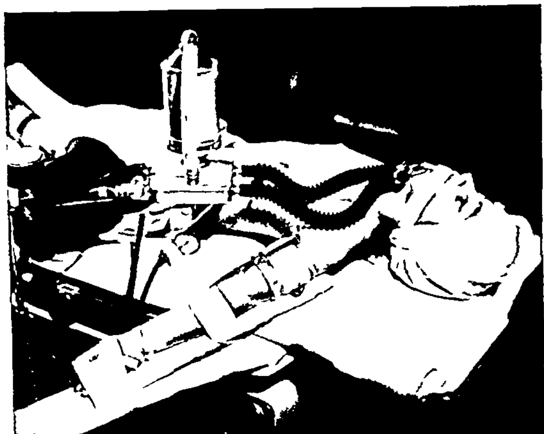


Fig 147 A patient prepared for a submucous resection The endotracheal technic with intravenous thiobarbiturate d tubocurarine and nitrous oxide anesthesia is used

child must establish quickly a habit of oral breathing because of the presence of nasal packs In view of the seepage of blood during the postoperative period the patient should be kept on his side in slight Trendelenburg position

Operation for Choanal Atresia

Choanal atresia usually suspected on the first day of life because of the severe respiratory obstruction, is surgically corrected by excision of the obstruction and insertion of plastic tubes to keep the nares patent In the management of such an infant, the anesthesiologist should (1) prevent any degree of depression of respiration (2) attend constantly to the

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of succinylcholine chloride 1 or 2 mg may be injected intravenously and the patient intubated orally Anesthesia is maintained with nitrous oxide and oxygen with a nonrebreathing valvular or absorption in circuit technic Small intermittent dosages of succinylcholine chloride may be administered throughout the procedure

At the end of the operation a tongue suture should be inserted so that the tongue can be pulled forward should postoperative respiratory obstruction occur Extubation is performed when the patient is awake and there is no evidence of the effects of the succinylcholine chloride These infants should be under constant observation in the nursery by the nurse, and the anesthesiologist should make frequent postoperative visits to observe the efficiency of the respiration Since preoperatively the lesion interfered with feeding the infant postoperatively oral fluids should be commenced as soon as he is awake and can breathe through his nose

OPERATIONS ON THE LARYNX

Laryngoscopy

Laryngoscopy is performed for diagnosis usually of a laryngomalacia or congenital web or for removal of obstructive lesions or foreign bodies

Diagnostic Infants or children scheduled for diagnostic laryngoscopy are premedicated with atropine alone They are not anesthetized but an anesthesiologist is ordinarily in attendance to supply oxygen immediately prior to the laryngoscopy and to monitor the heart with the precordial stethoscope and finger plethysmograph Bradycardia indicates the onset of acute hypoxia

Removal of Papillomas of the Vocal Cords Papillomas of the vocal cords require frequent removal by means of forceps or cautery If numerous they constantly threaten the patency of the airway The degree of respiratory obstruction is determined before anesthesia is begun and if there is any question of serious involvement of the airway preliminary tracheostomy should be performed under local anesthesia

In the older cooperative child papillomas are removed under local anesthesia If it is deemed advisable to remove the papillomas under general anesthesia atropine alone should be given for premedication On account of the possibility of severe encroachment of the papillomas on the glottic opening a small thin firm walled catheter of much smaller caliber than normally used for the age of the particular patient should be available This could be forced through the glottis in the event of severe respiratory

patency of the oral airway, since the nasal airway is either partially or completely obstructed, (3) provide for excessive blood loss, (4) perform endotracheal anesthesia to remove the anesthesiologist from the operative field and to prevent blood from entering the trachea, (5) use nonflammable and nonexplosive anesthetic agents because of the use of cautery, and (6) use anesthetic agents compatible with epinephrine-like drugs



Fig 148 An infant with posterior choanal atresia whose lips are being sucked in on inspiration A bag and mask for oxygen administration and an oral airway to keep a patent airway are at hand at all times prior to operation

To maintain the patency of the oral airway the infant must be kept aroused or even stimulated to encourage crying and breathing through his mouth A bag and mask for the administration of high oxygen concentration and an oral airway should be available (Fig 148) A cut-down in the saphenous vein at the ankle usually is done so that blood may be given when blood loss is severe Atropine 0 06 mg one half hour preoperatively may be given, but no sedatives are permitted

Because of a fear of depressing the respiration some anesthesiologists intubate these patients awake However if, on crying or on insertion of the oropharyngeal airway there is a patent oral airway a small amount

is hypoxic, oxygen can be administered through either the endotracheal tube or the bronchoscope If the child is uncomfortable nitrous oxide or cyclopropane can be added to the oxygen A large sandbag placed beneath the shoulders may assist in maintaining the airway, immobilizing the structures in the neck and providing the surgeon with a better exposure of the operative field



Fig 149 The surgeon is prepared to commence a tracheostomy The airway has been established with a bronchoscope with oxygen entering the lungs through the sidearm of the bronchoscope

The establishment of a patent airway by the endotracheal tube or bronchoscope (Fig 149) permits the surgeon to proceed unhurriedly and deliberately thereby minimizing the surgical complications of excess blood loss and accidental incision of the dome of the pleura with resultant

obstruction As a further precaution, during the induction of anesthesia the surgeon stands by ready to do an emergency tracheostomy

In order to maintain spontaneous respiration, the patient is anesthetized with ether insufflated through a mouth hook, as the endoscopist removes the papillomas with forceps An alternative nonflammable, nonexplosive technic providing considerable obtundation of the laryngeal reflexes is the administration of rectal tribromoethanol combined with topical anesthetization of the vocal cords Oxygen is insufflated through a mouth hook or a small stiff endotracheal catheter Although there may be strenuous objections to the small endotracheal catheter encroaching into the surgical field, the safe conditions afforded the patient with this method cannot be ignored Since tribromoethanol causes hypoventilation, respirations should be assisted by intermittent manual compression of the upper part of the abdomen The tribromoethanol technic is seldom employed today, for, although it provides ideal operating conditions, it entails prolonged attention by the anesthesiologist both preoperatively and postoperatively Still another method for removal of papillomas of the vocal cords is to apply a cuirass respirator over the thorax and abdomen and give the patient intravenous thiobarbiturates and muscle relaxants However, if this method is employed in small children, movement of the body by the suction of the cuirass respirator may complicate the surgery

Immediate postoperative care following the removal of papillomas includes meticulous observation of the infant or child by the endoscopist and anesthesiologist until it is certain that the patient can maintain a patent airway A cold, moist atmosphere is advisable to reduce any respiratory obstruction from edema Furthermore, a tracheostomy set, laryngoscope and endotracheal tube are always at the bedside of the patient during the recovery period

OPERATIONS ON THE TRACHEA AND BRONCHI

Tracheostomy

The performance of an emergency tracheostomy necessitated by severe respiratory obstruction allows little time for preanesthetic evaluation of the patient and renders depressant drugs and general anesthesia hazardous before establishment of the airway Oxygen is administered with a bag and mask, and the tracheostomy is done under local anesthesia In some instances relieving the obstructed airway with an endotracheal tube or bronchoscope facilitates the tracheostomy because there is less bleeding less restlessness, and a readily palpated stabilized trachea If the child

remains spontaneous with ether anesthesia A more rapid and comfortable technic providing good relaxation of the jaws with obtundation of the pharyngeal and laryngeal reflexes is with Fluothane anesthesia The usual 2 per cent Fluothane is used for the induction Following insertion of the bronchoscope, a 1 per cent concentration of Fluothane in 2 liters of nitrous oxide and 2 liters of oxygen is insufflated through the open arm of the bronchoscope This technic is only for the anesthesiologist who is willing to monitor continuously the cardiovascular system with the precordial stethoscope or other monitors and to record frequently the blood pressure The breathing remains spontaneous but any hypoventilation is corrected at intervals by closing the mouth of the bronchoscope with a finger During the examination intermittent manual compression of the lower sternum will also counteract the hypoventilation The emergence from the Fluothane-nitrous oxide anesthesia is very rapid and comfortable

In older children if no serious obstruction to respiration exists another technic is to anesthetize the patient with Fluothane or cyclopropane, using an adult circle absorber and a styletted needle inserted into a vein The patient is anesthetized until abdominal and jaw muscles are relaxed, accomplished by gradually taking control of the respirations An undersized endotracheal tube is inserted, through which artificial pulmonary ventilation is carried on The endotracheal tube is left in place, and the endoscopist passes the bronchoscope through the glottis beside the endotracheal tube

Immediate postoperative care for any patient following bronchoscopy includes ventilating the patient with oxygen, usually through an endotracheal tube which is inserted on removal of the bronchoscope When respiration is well established and the patient awake, the tube is removed and the patient turned on his side He is carefully observed for the next few hours and is put in a cold, moist, oxygen enriched atmosphere at the first sign of impending obstruction from subglottic edema

For Removal of a Foreign Body Several methods of anesthesia are available for bronchoscopy for removal of a foreign body the choice depending upon the skill of the anesthesiologist and the endoscopist If the endoscopist is inexperienced the patient should be kept breathing and this can be achieved with deep ether anesthesia and oxygen insufflated down the sidearm of the bronchoscope On the other hand, if the endoscopist and anesthesiologist are experienced ideal conditions can be provided for the endoscopist with the apneic technic, that is succinylcholine chloride given either subcutaneously or by an intravenous drip with in-

massive pneumothorax The endotracheal tube or bronchoscope is withdrawn as the tracheostomy tube is inserted If local infiltration has been employed, the skin around the tracheostomy tube can be loosely brought together without pain and therefore without movement of the exhausted patient

The retaining tapes of the tracheostomy tube must be firmly secured with a double tie so that the child or attendants cannot possibly remove it Accidental removal of the tracheostomy tube may be fatal especially in the first few postoperative days The inner section of the tracheostomy tube should never be omitted

The post-tracheostomy patient requires constant nursing care, preferably in the acute treatment room Frequent aspiration of the tracheostomy tube is essential A humidified, cool atmosphere can be provided by a Croupette In spite of the aspirations of the tracheostomy tube, respiratory obstruction may occur, in which event the inner section of the tracheostomy tube should be removed cleaned, and replaced As previously stated, intentional removal of a tracheostomy tube within the first few days of the tracheostomy may be hazardous since asphyxia and death may occur if the tracheostomy passage cannot be re-entered rapidly, we have seen a few instances of acute hypoxia and also two deaths from this cause A small catheter passed through the lumen of the tracheostomy tube well into the trachea makes it possible on removal of the tracheostomy tube to reinsert quickly the tube either by threading it over or directing it alongside the catheter into the trachea If difficulty is encountered oxygen can be administered through the catheter The tracheostomy tube should never be removed without the attendance of the surgeon

If each detail in the management of a tracheostomy is attended to meticulously avoidable fatalities will be prevented

Bronchoscopy

For Diagnosis or Aspiration Bronchoscopy for diagnosis, relief of atelectasis, or removal of secretions is often done with the infant or child awake, the safest method if there is obvious obstruction to the airway

If a decision is reached to anesthetize the patient, scopolamine or atropine is given one half hour before surgery as preanesthetic medication

General anesthesia can be accomplished in any one of numerous ways For instance the patient can be anesthetized to a deep plane of ether anesthesia The ether mask is removed, and following adjustment of the position of the head and shoulders, the bronchoscope is passed Breathing

ensues the cuirass respirator is turned on and pulmonary ventilation is artificially maintained

Bronchogram

With the roentgenologist and anesthesiologist working as a team bronchograms obtained today in infants and children are far superior to those of a few years ago Bronchography is conducted in a darkened fluoroscopy and x ray room all personnel being gowned with lead aprons to protect them from the roentgen rays

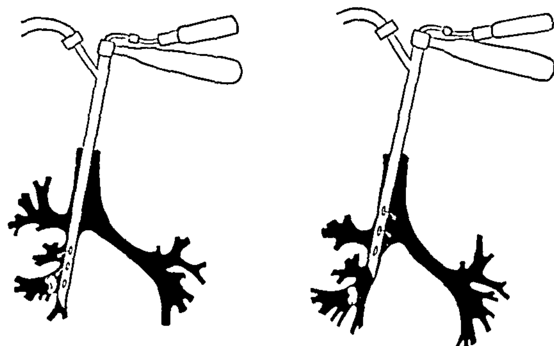


Fig 151 *(Left)* The bronchoscope is deep in the right bronchus Occlusion of the mouth of the bronchoscope will ventilate only the middle lobe on the right side since a peanut occludes the lower lobe With the bronchoscope in this position the left lung cannot be ventilated *(Right)* With the bronchoscope withdrawn occlusion of the port of the bronchoscope will ventilate all areas of the lung except where the foreign body occludes the lower right lobe

To obtain a bronchogram, the radiologist inserts a polyethylene catheter into the suction port in the angle piece of the endotracheal tube A syringe containing propyliodone oily suspension (Dionosil Oily) is attached to the polyethylene catheter The lights being turned out for fluoroscopy, the roentgenologist directs his assistant to instill Dionosil while he attempts to visualize the bronchi of one lung at a time When the dye has filled the bronchi satisfactorily, a spot film is taken, after which the lights are turned on and an attempt made to remove some of the Dionosil by aspiration,

sufflation of nitrous oxide or cyclopropane Succinylcholine chloride is increased with the slightest return of abdominal muscle tone Oxygen flows down the bronchoscope sidearm (Fig 150), out through the pores of the shaft of the bronchoscope and into the contralateral lung (Fig 151)



Fig 150 During this bronchoscopy for removal of a foreign body oxygen is insufflated through the nipple on the bronchoscope Occasionally the endoscopist inflates the lungs by occluding the open arm of the bronchoscope or the anesthesiologist artificially ventilates the lungs by applying intermittent positive pressure on the upper part of the abdomen

Additional ventilation can be obtained by occasional intermittent pressure on the upper abdomen Any slowing of the pulse or cyanosis is the signal for more vigorous ventilation achieved by increasing the flow of oxygen and intermittently occluding the open end of the bronchoscope with one finger Such intermittent inflation may be maintained for some time enabling the endoscopist to remove a foreign body with ease, and avoiding trauma and hemorrhage

Another method of anesthesia for the experienced endoscopist and anesthesiologist is to apply a cuirass thoracic respirator and then give the patient intravenous thiobarbiturates and muscle relaxants When apnea

ensues the cuirass respirator is turned on and pulmonary ventilation is artificially maintained

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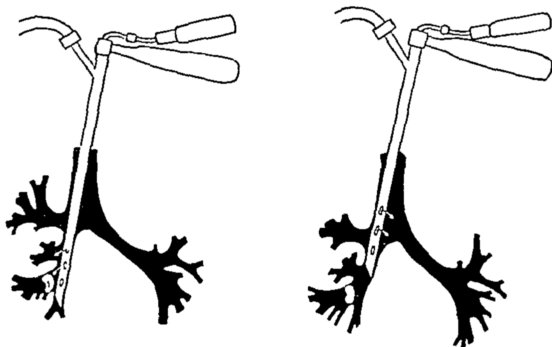


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while the rest will be absorbed quickly into the body Following this, the bronchi of the other lung are also fluoroscoped and x-rayed in the same manner In patients with severe dysfunction of the lung the amount of Dionosil or radiopaque substance must be kept at a minimum, otherwise severe respiratory obstruction may occur

Scrupulous preanesthetic evaluation is essential in an infant or child scheduled for bronchography, for considerable secretions with impairment of pulmonary function may be present in a patient with severe bronchiectasis If possible, bronchograms are done preferably in the early afternoon after the patient's lungs are cleared out by coughing or by postural drainage

Premedication consists of scopolamine alone A precordial stethoscope, blood pressure cuff, and monitor are applied A needle inserted in the saphenous vein at the ankle is attached to a 0 2 per cent succinylcholine chloride drip, in infants, a cut-down in the saphenous vein at the ankle is necessary for reliable results A three-way stopcock between the needle and the infusion fluid is valuable for the intravenous administration of more concentrated succinylcholine chloride should the patient's muscle relaxation wane thereby endangering a satisfactory bronchogram by coughing and alveolation of the instilled dye

The patient is anesthetized with intravenous thiobarbiturate given cautiously in small dosages Then relaxation is achieved with succinylcholine chloride, and an endotracheal tube is inserted and connected with a bag and nonrebreathing valve for inflation of the lungs with oxygen This system provides a nonexplosive nonflammable technic

Two anesthesiologists are necessary for the proper conduct of a bronchogram One anesthesiologist guides the ventilation of the lungs and checks the carotid pulse while his assistant at the foot of the table regulates the rate of infusion or injection of the drugs Since the precordial stethoscope must be removed during the bronchoscopic examination, it is advisable to employ an esophageal stethoscope lucid to x-rays

If the heart slows or fluoroscopy is unduly prolonged at any time, the anesthesiologist inflates the lungs very gently with oxygen The lungs also are slowly and gently inflated after the fluoroscopy of one lung and just prior to aspirating the dye and more vigorously ventilated before proceeding to visualization of the other lung

At the end of the procedure the Dionosil is removed again by aspiration, when the patient's respirations have fully returned the endotracheal tube is removed Because of the pulmonary pathology, the anesthesiologist

observes the patient until the return of consciousness is complete and there are no residual effects of the muscle relaxant

OPERATIONS ON THE LUNGS AND PLEURA

Thoracotomy and Thoracentesis

Thoracotomy and thoracentesis are rare in infants and children since the advent of antibiotics, but occasionally a chronic empyema forms, will not absorb, and must be drained by an opening involving removal of part of a rib

Infants and children with this complication are chronically ill, often anemic, usually need blood transfusion before or during operation, and require delicately controlled anesthesia Overdose of sedatives and anesthetic agents should be avoided, scopolamine alone is sufficient for premedication

Local anesthesia may be given in older children, in infants and young children minimal amounts of cyclopropane are adequate, and mask technic is permissible since the procedure is short, and well-formed pleural adhesions prevent mediastinal shift

Decortication

Some cases of inadequately or unsuccessfuly treated empyema progress to a crippling fibrothorax These patients being chronically debilitated, anemic, and with a low blood volume show a weakened myocardium from prolonged infection, chronic hypoxia, and invalidism Full expansion of the lung and removal of the suppurative process are accomplished by decortication, which is difficult, time consuming and usually accompanied by severe blood loss

Premedication is scopolamine alone narcotics and sedatives being omitted or used sparingly A cut down is necessary to assure a portal for blood transfusion in infants, in older children, the insertion of two large-bore styletted needles into accessible veins is adequate

Anesthesia is induced and maintained with cyclopropane, circle absorption technic, with controlled respiration, intubation being facilitated by succinylcholine chloride intravenously When the surgeon uses electric cautery, a nonexplosive, nonflammable combination of anesthetic agents such as intravenous meperidine (Demerol), nitrous oxide, and succinylcholine chloride is used Fluothane, if used, will reduce the blood loss and operating time

The blood loss which occurs with this operation necessitates immediate and vigorous transfusion at the commencement of surgery and at a rate equal to the operative hemorrhage during surgery

After the operation is over, a water-seal drainage tube is inserted in the pleural cavity, providing for gradual expulsion of air, blood, or serum and allowing expansion of a lung so long compressed Cold, moist atmosphere is employed postoperatively to prevent an increase in subglottic edema which may arise from prolonged intubation For patients with severe discomfort, analgesics such as meperidine (Demerol) are administered in small dosages

Lobectomy, Pneumonotomy, Pneumonectomy, and Excision of Lung Cysts

For an intelligent management of the anesthesia in the pediatric patient presented for these intrapleural operations, the anesthesiologist must understand the pulmonary pathology of the disease involved This he can accomplish by studying the history, physical examination, laboratory analysis of the blood and urine pulmonary function tests bronchoscopy or bronchogram, and roentgenologic report of the thorax, such information can then be correlated with the reports of the pediatrician and surgeon

Lobectomy is rare in infants and children as compared to adults The indications for the operation are an atelectatic, emphysematous, or bronchiectatic lobe, or a lung abscess Pneumonotomy for removal of a foreign body and pneumonectomy also are performed only on rare occasions in pediatric practice Excision of a localized cystic malformation of the lung is probably the most frequently performed lung operation in infants A large clear cyst shown by x-ray usually indicates a communication between the cyst and a bronchus

The anesthetic management for a lobectomy, pneumonectomy, or excision of a lung cyst is similar with the following precautions obtaining (1) depression of respiration is avoided (2) lost blood is replaced, (3) the lungs are adequately ventilated, (4) mediastinal swing is prevented and (5) overdistention of a communicating lung cyst is prevented

Preanesthetic medication in a dosage suitable to the physical status and weight of the patient is usually a combination of some opiate and scopolamine The opiate is omitted in the infant

Immediately before surgery preparations are made for blood transfusion through a venous cut down in infants or through two large-bore styletted intravenous needles in older children

Anesthesia is induced with either cyclopropane by the circle absorption

technic or with a small amount of a thiobarbiturate intravenously, and the anesthesia maintained with cyclopropane, using controlled respirations If a communicating cyst becomes overdistended emergency thoracotomy and delivery or puncturing of the cyst are urgent To save the patient's life a needle may have to be passed into the cyst through the intact chest wall If cautery is used, a nonexplosive technic of intravenous opiates combined with nitrous oxide and fortified with small increments of a muscle relaxant to secure controlled respirations can be used In some of these operations, we have obtained nonflammable, nonexplosive conditions with a combination of Fluothane and nitrous oxide The advantages afforded by Fluothane are reduced blood loss and operating time, decreased secretions in the respiratory tract, and rapid recovery from anesthesia

Marked mediastinal swing hindering the work of the surgeon, can be prevented by maintaining a slight positive pressure on the breathing bag during exhalation Intermittent endotracheal suction is generally necessary to remove secretions in the air passages, and should be executed quickly, after oxygenation Endotracheal technic provides a reliable airway through which the lungs can be ventilated and mediastinal swing avoided Periodically, the collapsed lung should be inflated to restore oxygen saturation of the blood, to prevent respiratory acidosis, and to avoid stubborn atelectasis The continuous-recording carbon dioxide analyzer serves as a monitor for respiration and circulation (Fig 152) Eight and 9 per cent carbon dioxide may be recorded, usually accompanied by increasing heart rate and rising blood pressure Increased pulmonary ventilation during a four- or five-minute period of surgical stasis reduces the alveolar carbon dioxide, decreases the heart rate and reduces the blood pressure A sudden decrease in recorded carbon dioxide may mean occluded bronchi or severe shock Overdistention of the lungs, however, is to be condemned since, if prolonged, it may embarrass circulation

Closed drainage with a water seal or trap should be provided to allow expansion of the remainder of the lung during the recovery period, if not, the lung should be expanded just prior to complete closure of the chest From then on the anesthesiologist should watch for the occurrence of a tension pneumothorax, which will threaten the life of the patient by occluding the bronchi and the superior and inferior venae cavae

At the end of surgery, the pharynx, trachea and major bronchi are aspirated and the patient is extubated when spontaneous respirations are well established An x ray film of the thorax should be taken on the operating table to evaluate the immediate postoperative condition of the



Fig 152 For removal of a lung cyst an esophageal stethoscope is in the esophagus A polyethylene sampling catheter of the carbon dioxide analyzer is in the port of the angle piece of the endotracheal tube Blood pressure cuff is applied Needle electrodes are visible in the right arm and right leg and there is another electrode in the left leg Styletted needles are in place in the feet Often these needles are put into the hand which is more convenient for the anesthesiologist

lungs In the early recovery period the patient is placed in a cool, moist atmosphere containing a high oxygen concentration Postanesthetic aspiration of the trachea promotes coughing with consequent removal of secretions and expansion of the lungs The institution of intermittent positive pressure breathing may help to expand the lungs Small doses of opiate-like drugs give a distinct measure of comfort On each postanesthetic visit, the anesthesiologist should observe the fluctuations of the fluid in the tubing of the water seal When the lung is fully expanded the fluctuations usually cease He should also observe any marked rise of bloody fluid in the drainage bottle and other signs of blood loss and report them immediately to the surgeon Some of these patients develop gastric distention which may be relieved and its recurrence prevented by the insertion of a gastric tube which is retained postoperatively for a day or two Again it is the combined efforts of the surgeon, pediatrician, anesthesiologist and recovery room nurses that contribute to a successful outcome for the patient

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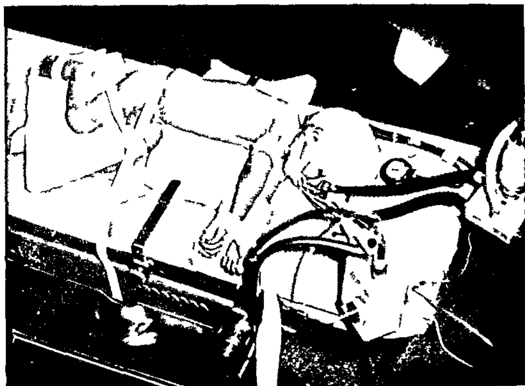


Fig 152 For removal of a lung cyst an esophageal stethoscope is in the esophagus A polyethylene sampling catheter of the carbon dioxide analyzer is in the port of the angle piece of the endotracheal tube Blood pressure cuff is applied Needle electrodes are visible in the right arm and right leg and there is another electrode in the left leg Styletted needles are in place in the feet Often these needles are put into the hand which is more convenient for the anesthesiologist

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CHAPTER 20

OPERATIONS ON THE CARDIOVASCULAR SYSTEM

Realizing that each medical center develops its own modus operandi and that there is more than one method of anesthesia for operations on the cardiovascular system, we offer some of the procedures that have been used in infants and children

BASIC PREPARATIONS FOR CARDIAC SURGERY

For operations on the cardiovascular system the best preparation for the anesthetic management according to Smith is a thorough understanding of the abnormal physiology of the patient coming to operation and the expected effect of the operation upon this unnatural physiology " * In Chapter 5 (pp 99–124) is a brief resume of some of this abnormal physiology occasioned by the classical cardiovascular lesions, but it must be noted that even patients with the same diagnosis vary in the degree of efficiency of their cardiovascular systems In our institution the anesthesiologist has a special session with the cardiologist and the surgeon, at which the particular case is discussed prior to the surgery, thereby assisting the anesthesiologist to make an intelligent evaluation of the patient

The anesthesiologist then determines and orders the preanesthetic medication in relation to the severity of the cardiac disease Patients who are cyanotic or have been in cardiac failure receive one-half the usual sedative premedication for the particular age group Some of these patients

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10 Digoxin—reduces pulmonary edema and heart rate
11 Heparin
12 Protamine sulfate—neutralizes heparin

In the following presentation, operations on the cardiovascular system are divided into two major groups operations on the heart and pericardium and operations on the arteries and veins

OPERATIONS ON THE HEART AND PERICARDIUM

Cardiotomy

For Atrial Septal Defect (Primum and Secundum) Although there is extensive use of the artificial heart lung machine for exposure and suturing of an atrial septal defect, it is our present opinion that the following described hypothermic technic produces comparable results In our series to date, of eighty-seven cases of ostium secundum there have been no deaths and of ten cases of ostium primum only three deaths

After the blood pressure cuff and precordial stethoscope are applied, the patient is anesthetized with cyclopropane by the circle absorption technic During this induction period, a second anesthesiologist performs auxiliary services, including the insertion of styletted needles in a vein of each foot using at least 18 gauge needles If the veins are small, as in infants, a cut-down is performed, and an 18-gauge polyethylene tubing is secured in the vein Each limb containing the intravenous needle or cut down is strapped to padded splints with adhesive tape Subsequently 5 per cent glucose in water is administered intravenously to prevent dehydration and thrombosis, particularly in patients with hemoconcentration, however fluid administration must be slow and in minimal amounts to avoid pulmonary edema

The cardiac rate and rhythm are monitored by an electrocardiograph (Fig 153), using needle electrodes If a bradycardia of between 40 and 60 beats per minute occurs, fresh atropine, 0 06 mg (gr 1 1000), is given intravenously Should the heart rate not accelerate to between 80 and 90 beats per minute the same dosage of atropine is repeated Succinylcholine chloride, 0 5 mg/kg of body weight, is given intravenously, and intubation is accomplished Immediately following insertion of the endotracheal tube the patient s lungs are ventilated with oxygen, an esophageal stethoscope is put in place, and the precordial stethoscope removed After a continuous recording thermometer is inserted in the esophagus to monitor the

are considerably underweight and in such infants or children, the sedative premedication is further reduced

Because of the critical and sudden changes which can occur in the hemodynamics during an operation on the cardiovascular system, extensive preparations must be made so that exigencies may be attended to with dispatch The night before a major cardiac operation, the anesthesiologist prepares and organizes the anesthetic equipment and medications In addition to the routine anesthetic equipment the following electronic equipment is present at every cardiac operation for use by either the cardiologist, surgeon or anesthesiologist

1 Electrocardiograph and leads, with three 21-gauge needle electrodes

2 Oscilloscope

3 Infrared analyzer for continuous recording of carbon dioxide in the endotracheal tube, as a respiratory and cardiovascular monitor

4 Esophageal continuous recording thermometer (Wheatstone bridge type)

5 Defibrillator—range 170 to 220 volts for 0 1 to 0 5 second duration

6 Multichannel recorder

7 Transducers to convert direct arterial and venous pressures into electrical energy in which form it can be recorded on the oscilloscope or multichannel recorder

8 Electroencephalograph with needle leads (particularly necessary with heart lung machine)

Depending upon the technic to be used equipment is prepared for the hypothermic technic the heart lung machine technic, or a combination of both technics

The following special medications are prepared in labeled syringes before surgery they are then placed on the top of the portable anesthetic cabinet

1 Succinylcholine chloride (20 mg/ml)—muscle relaxant

2 Decamethonium (Syncurine)—muscle relaxant

3 Atropine (0 06 mg/ml), freshly prepared—increases heart rate

4 Calcium chloride (100 mg/ml)—improves myocardial tone

5 Calcium gluconate (100 mg/ml)—improves myocardial tone, but less effectively than calcium chloride

6 Methoxamine (Vasoxyl) (1 0 mg/ml)—cardiovascular stimulant

7 Adrenalin (0 1 mg/ml or 1 10 000)—cardiovascular stimulant

8 Noradrenalin (Levophed) (1 10 000)—cardiovascular stimulant

9 Cedilanid—reduces pulmonary edema and heart rate

we have had only one instance of ventricular fibrillation during this rapid method of cooling

Calibration of the carbon dioxide analyzer is the next procedure, whereupon the microcatheter of the analyzer is inserted into the endotracheal tube for a distance of approximately 3 cm As the body temperature drops, the carbon dioxide production decreases and the alveolar carbon dioxide falls The drop in alveolar carbon dioxide is even more pronounced because of the artificial pulmonary ventilation carried on by the anesthesiologist Absolute values of alveolar carbon dioxide are not as important as are the relative changes in the alveolar carbon dioxide tension As the body

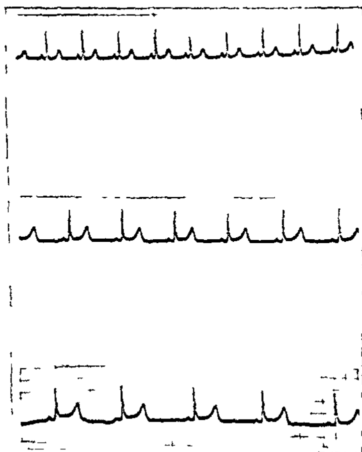


Fig 154 Electrocardiographic changes during hypothermia and cyclopropane anesthesia *(Upper tracing)* Body temperature is normal *(Middle tracing)* Temperature is 34 C with a bradycardia and peaked T wave *(Lower tracing)* Temperature is 30 C

temperature drops, the electrocardiogram changes with the appearance of the bradycardia (Fig 154)

The patient is cooled in about 30 minutes to approximately 33° C, at which time he is removed from the ice and postured on the operating table

body temperature, the patient is then lifted into a tub of ice water containing chipped ice, the head being supported on a pillow A sheet is placed over the patient, who is then completely covered with ice



Fig 153 Hypothermia (1) Esophageal stethoscope (2) carbon dioxide analyzer (3) esophageal thermometer (4) ECG leads (5) crushed ice

Water, with its high specific heat of 1 cal/g° C and the heat of fusion of ice being equal to 80 cal per gram, makes an ideal medium for the rapid removal of heat from the body Of such brief duration is the anesthetic and surgical procedure that, in our experience the additional hazard of employing a heat exchanger to cool the heparinized blood extracorporeally has not been warranted In approximately 600 hypothermia cases,

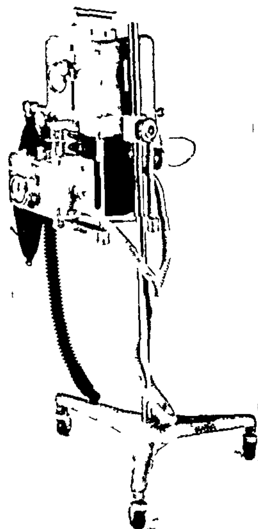


Fig 156 The Bird assistor/controller This versatile pneumatically controlled ventilator efficiently ventilates the lungs of the infant or child It is either volume or pressure controlled with adjustable positive and negative pressures

centration is reduced, and small dosages of thiobarbiturates are given intravenously At times we use with the hypothermia various combinations of nonexplosive, nonflammable anesthetic agents and relaxants such as nitrous oxide and succinylcholine chloride or decamethonium (Syncurine) For the last thirty cases of atrial septal defect we have used the hypothermic technic together with a combination of Fluothane and nitrous oxide, with *no deaths and only two instances of easily reversed ventricular* fibrillation The advantages of this combination of anesthetic agents appear to be reduced bleeding lessened myocardial irritability, shorter operating time, nonexplosive and nonflammable conditions, and rapid emergence from anesthesia

When surgery has progressed to the point where the inflow and out-



Fig 155 Supine posture for repair of atrial septal defect under hypothermia (1) ECG leads (2) carbon dioxide analyzer (3) two 18 gauge styletted intravenous needles (4) patient s identity band

in the supine position (Fig 155) A further drop in body temperature is expected the optimum low level being between 31° and 30° C At the beginning of surgery a bottle of matched blood is suspended, and the dextrose infusion removed

Anesthesia is maintained with minimum amounts of cyclopropane, and the respiration is controlled either with manual compression of the breathing bag, or with a mechanical ventilator (Fig 156) If extrasystoles occur, signifying increased irritability of the myocardium the cyclopropane con-

electrocardiogram and precordial stethoscope is mandatory during this procedure

The two drainage tubes are double clamped, and the patient is placed gently in his bed and returned to the recovery room If he shows signs of hypoxia he is placed in a Croupette supplied with a high moisture and oxygen atmosphere, but without ice, until the body temperature reaches normal Traumatic laryngitis is practically unknown with hypothermia No active treatment is carried out to raise the body temperature Following Fluothane anesthesia, shivering is more frequently seen than following other anesthetic agents, and restoration of body temperature is rapid If the patient is extremely restless from pain, very small dosages of meperidine (Demerol) may be given intravenously In conjunction with the surgeon, the anesthesiologist notes the color of the patient, the recovery of consciousness, the body temperature, the amount of blood in the drainage bottles and any increases in pulse rate, or hypotension

All patients who have undergone cardiac surgery have endotracheal suction performed by the anesthesiologist the day of surgery and subsequently as indicated Again, the usual precautions of administering 100 per cent oxygen by bag and mask between each rapid tracheal aspiration must be exercised Intermittent positive pressure breathing during the first few postoperative days helps to expand the lungs

For Ventricular Septal Defect For repair of a ventricular septal defect an artificial heart-lung machine and hypothermia are used The machine maintains a circulation of oxygenated blood in the brain Although the surgeons shoulder the greater share of the responsibilities in the management of the artificial heart-lung machine there are still many functions to be carried out by the anesthesiologist

A nonexplosive technic is usually favored because of extensive use of electrocautery and electronic devices Induction of anesthesia is accomplished with a combination of Fluothane and nitrous oxide, using either a nonrebreathing valvular or circle filter technic When relaxation is adequate, the patient is intubated A mechanical ventilator together with monitoring devices such as the esophageal stethoscope and thermometer, electrocardiograph, and electroencephalograph are attached to the patient

The patient can be cooled by placing him in an ice water tub or by attaching a heat exchanger in which the heparinized arterial blood is cooled as it flows through a series of small tubes surrounded by the controlled-temperature water medium The internal temperature of the patient can be cooled 10° C in less than five minutes with a heat exchanger, and it

flow tract of the heart is about to be clamped, two procedures are carried out blood is pumped into the patient, and succinylcholine chloride or decamethonium (Syncurine) is injected intravenously to prevent respirations during the ensuing five to fifteen minutes Upon clamping the circulation, the alveolar carbon dioxide drops, since pulmonary capillary blood flow is clamped off The electrocardiogram usually shows bradycardia, extrasystoles, and A-V dissociation, and the pupils dilate During this period of total circulatory occlusion (in our series, from three to thirteen minutes), the surgeon rapidly repairs the atrial septal defect, fills the atrium with normal saline, closes the atrium, and then releases the clamps from the great vessels as the anesthesiologist inflates the lungs A strong myocardium rebounds immediately and should be accompanied by an elevation in alveolar carbon dioxide and a reduction in the size of the pupils While the electrocardiogram may show some irregularities for a few minutes, the most reliable signs of the patient's condition are the visible color, size, and contractions of the heart

On rare occasions there is a critical time during the closure of the pericardium when blood pressure drops, the heart becomes feeble, and alveolar carbon dioxide is acutely depressed The anesthesiologist immediately advises the surgeon of the patient's condition before cardiac arrest ensues It appears that the heart has become overdistended by overzealous blood replacement, for release of the pericardial sutures rapidly restores the efficiency of the heart

At the completion of pericardial repair, the chest wall is closed and a drainage tube is left in each chest and attached to water-seal drainage bottles which rest on the floor The lungs are inflated and the patient resumes his own respirations The patient is generally semiconscious and moving while the dressings are being applied over the wound One styletted needle is removed from the foot while the other is left in place for further use if necessary The esophageal thermometer and stethoscope are removed

The trachea and bronchi are cleansed by passing a suction catheter through the endotracheal tube However the catheter is never left in the trachea too long at one time, since prolonged coughing may cause severe hypoxia Between tracheal aspirations the patient is well oxygenated and a nasogastric tube is passed and secured The patient is extubated, and a mask and bag with high oxygen concentrations immediately applied to his face A short period of intermittent positive pressure breathing sometimes improves the patient's color, but vigilant monitoring of the heart with

ingly important in the postoperative care of these patients is supervision by trained recovery room personnel, who learn to detect ominous signs and report them immediately to the physician in charge

Pericardiotomy

Anesthesia for pericardiotomy can be very hazardous because of the heart's limited diastole and reduced output The management of anesthesia is similar to that for repair of an atrial septal defect, however, only a very mild degree of hypothermia, down to a level of about 35° C, is used

Pulmonary Valvulotomy

The anesthesia for pulmonary valvulotomy is identical with that of the hypothermic technic employed for the repair of an atrial septal defect If there is an associated atrial septal defect, the heart can be opened and closed twice, four or five minutes apart On the first opening the pulmonary valve is opened, and on the second the atrial septal defect is repaired

Infants or children who undergo pure pulmonary valvulotomy usually have an uneventful recovery However, if there are associated lesions or if there is considerable hypertension in the right ventricle prior to surgery, the prognosis is generally poor, for even though these patients may appear to be in good condition for the first few hours postoperatively, sometimes they later develop dyspnea pallor, and enlarged liver, with demise occurring late on the operating day To guard against this catastrophe the blood pressure should be taken frequently and the slightest degree of hypotension controlled by increasing the phenylephrine (Neo-synephrine) drip since the output of the right ventricle must be maintained to sustain pulmonary capillary blood flow

Cardiac Catheterization and Angiocardiography

Cardiac catheterization and angiocardiography are frequently performed to diagnose congenital malformations of the heart Many cardiologists perform these procedures successfully with the patient under heavy premedication

The rare uncooperative child, however may require general anesthesia Most infants or children scheduled for these procedures have serious cardiac disability and are grave anesthetic risks Premedication is the same as that outlined for all cardiac operations, that is, scopolamine and one-half the normal dosage of sedatives For catheterization, properly typed blood is available to replace blood loss from repeated sampling

also affords a rapid, convenient method of rewarming the patient Further experience with the heat exchanger will determine whether it offers any worthwhile advantages over external cooling with ice water

The mean femoral arterial pressure is recorded on an aneroid manometer and the femerol venous pressure on a water manometer If a permanent record is required, transducers are employed, which, in turn, are connected to a multichannel recorder The arterial pressure provides the anesthesiologist with an excellent indication of the dosage of Fluothane being administered

Although various surgical procedures for repair of ventricular septal defect are in practice throughout the world, we shall briefly outline only one of them in an attempt to furnish a background for the anesthetic management of such an operation

Following the cooling of the patient, the surgeon performs the thoracotomy and cannulates the superior and inferior venae cavae The cannulae are then connected to the disk oxygenator From the oxygenator, tubing is connected to the cannulated subclavian artery The heparinized, oxygenated blood is propelled into the subclavian artery by a pump, whose output is regulated in accordance with the mean arterial pressure of the patient The pulmonary artery and the aorta are occluded close to the heart by adjustable ligatures The descending aorta is clamped distal to the cannulated subclavian artery so that the oxygenated blood is diverted into the upper extremities and head Methacholine chloride (Mecholyl), a powerful cholinergic drug, is injected into the heart, bringing it to a standstill During the ventriculostomy the clamp close to the heart on the aorta is released occasionally to allow for coronary filling causing the heart to become pinker Following the repair and closure of the heart, all the clamps are removed and the heparin neutralized by an equal quantity of protamine sulfate If the heart looks flabby small, and empty more blood is required If it is distended transfusion is stopped The heart, blood pressure, and venous pressure are observed for a short time to establish the fact that a stable adequate circulation exists The chest is closed, as in atrial septal defect repair

Postoperative care absorbs the efforts of the surgeon cardiologist, and anesthesiologist each one being concerned with complete return of the integrity of respiration circulation and cerebral and renal function The patient may require tracheal aspirations and intermittent positive pressure breathing by the anesthesiologist treatment of cardiac arrhythmia or failure by the cardiologist, and over all supervision by the surgeon Exceed

half to four hours), the patient is placed in a Croupette postoperatively to prevent subglottic edema Any movement of the patient should be done carefully to prevent hypotension



Fig 157 Method of increasing venous return to right atrium illustrating manual compression of the abdomen and elevation of the legs

Cardiac Massage

When the anesthesiologist through the precordial stethoscope or other cardiac monitors no longer detects a heartbeat, or clinical signs register acute cardiac failure an incision parallel to the ribs approximately at the level of the fourth left interspace is immediately made If following the incision there is no bleeding or only a trickle of severely cyanotic blood, the decision to open the thorax and commence rhythmic compression of the ventricles between the thumb and fingers is confirmed In infants this may have to be done with the two index fingers or by compression of the heart against the inferior surface of the sternum Well-performed cardiac massage will produce a palpable pulse and a rise in alveolar carbon dioxide

If the heart is flabby, 2 ml of calcium chloride, 10 per cent, should be injected into the left ventricle and pressure applied intermittently to the abdomen (Fig 157), while the patient is placed in the Trendelenburg position to fill the right atrium with blood The heart which has been in

In instances when general anesthesia is required, a nonexplosive, nonflammable combination of anesthetic agents such as nitrous oxide supplemented with trichlorethylene is used to induce anesthesia When the patient is anesthetized the electrocardiograph and pneumotachograph are attached to him A needle is inserted into a vein and a very small amount of thiobarbiturate is given slowly, intravenously Next succinylcholine chloride is administered intravenously or intramuscularly The patient is then intubated, and anesthesia is maintained with a combination of nitrous oxide and small doses of thiobarbiturates or meperidine (Demerol) intravenously Respirations are assisted throughout The oxygen in the endotracheal tube is monitored by a continuous-recording paramagnetic analyzer, keeping it at a level of 20 to 30 per cent, according to the condition of the patient

Local anesthetic is injected into the arm by the cardiologist who inserts the catheters in the brachial artery and in an antecubital vein, these catheters being connected to the transducers The path of the catheter is observed through the fluoroscope, which is usually screened with flexible lead curtains to protect the personnel Pressure recordings and samples of blood for oxygen tension are taken at various sites Continuous visibility of the electrocardiogram and brachial artery and right ventricular pressures are available to the anesthesiologist and cardiologist on the oscilloscope

If a right to-left shunt is suspected, an angiocardiography is performed immediately after cardiac catheterization The patient still anesthetized and intubated, is moved from the fluoroscopy table to a table equipped for taking rapid serial x-rays The electrocardiograph, as a cardiac monitor, remains attached to the patient If upon the intravenous injection of a small test dosage of diatrizoate sodium (Hypaque) no circulatory changes are observed succinylcholine chloride is given intravenously or intramuscularly to assure apnea and quietude of the patient during the critical moment of injection and filming of the angiocardiogram The full dosage, 1 ml of Hypaque per kg of body weight, is then injected rapidly into the vein and the rapid serial x-ray exposures are made A sinus tachycardia and hypotension may follow this rapid injection If the hypotension is severe, an electrocardiogram indicative of hypoxia may appear, and the administration of oxygen and vasopressors as well as placing the patient in the Trendelenburg position may be required

Following the filming the wound is sutured The patient is given high oxygen concentrations to remove the nitrous oxide from the body, and is then aroused and extubated Usually, because of the length of the combined cardiac catheterization and angiocardiography (from one-and one-

plications seldom arise during surgery The clamping of the ductus stops the leak in the systemic system, and, at this time, the systolic and diastolic murmurs are no longer heard through the esophageal stethoscope A remaining diastolic murmur may be due to an aortic insufficiency from a dilated left ventricle If a large ductus has been occluded and there is no pulmonary vascular obstruction a sharp elevation of the diastolic pressure occurs and the heart rate slows



Fig 158 A patient in the right lateral position preparatory to transection of a patent ductus arteriosus In this normothermic patient when the left lung is collapsed for the transection the carbon dioxide in the endotracheal tube may rise to 6 or 7 per cent and the pulse rate may increase

Some patients with patent ductus arteriosus show severe damaging effects from their altered hemodynamics So much blood is shunted from the systemic to the pulmonary system that the pulmonary arterial pressure rises and peripheral resistance in pulmonary vessels increases, the right ventricle hypertrophies and dilates the right atrium dilates, and the liver becomes enlarged The rise in pulmonary artery pressure can be so severe as to reverse the flow of blood so that a large part of the blood is being pumped by the right ventricle through the ductus into the aorta This right to left shunt may cause cyanosis A right to left shunt of blood is

asystole usually resumes a normal beat if restoration is possible Continued flabbiness or frequent asystoles constitute a grave omen Cardiac arrest appears to be a rapidly diminishing complication in the operating room and even more apparent is the very high percentage of complete recoveries following undelayed digital cardiac compression

Cardiac Defibrillation

The clinical signs of ventricular fibrillation are the same as with a heart in asystole, and the diagnosis discerned from an electrocardiograph monitor is confirmed on opening the thorax and observing the heart in ventricular fibrillation The fibrillating heart is immediately massaged then defibrillated A heart which has firm myocardial tone can usually be defibrillated Two paddles covered with saline soaked gauze are applied to each side of the heart If the heart is fibrillating, but has good tone, a single shock with 170 volts for 0 1 second generally arrests the heart, but if this fails to arrest the heart, the left ventricle of the flabby heart should be injected with 1 or 2 ml of 10 per cent calcium chloride and then shocked with 220 volts for 0 1 second With the heart at a standstill cardiac massage is resumed In a reparable heart a slow heartbeat will be initiated spontaneously but the contractions soon become rapid and vigorous The same heart can often fibrillate and be defibrillated many times with a satisfactory outcome A heart which remains dilated, blue, and flabby with a slow ventricular fibrillation for a long period of time most likely is an irreparable heart

OPERATIONS ON THE ARTERIES AND VEINS

Transection of Patent Ductus Arteriosus

With patent ductus arteriosus, the left ventricle of the heart is overworked pumping oxygenated blood not only through the systemic vessels but also redundantly through the patent ductus arteriosus into the pulmonary circulation The ductus also causes a leak of varying proportions in the systemic system The greater this leak the lower the diastolic pressure the greater the pulse pressure and the more apparent is the water hammer pulse

The anesthetic management for transection of patent ductus arteriosus is similar to that set forth for atrial septal defect repair except that in the case of patent ductus arteriosus the patient is in the right lateral position (Fig 158), and in the uncomplicated case, hypothermia is omitted Com

and intermittent positive pressure breathing are performed when rales are heard in the chest

Arterial and Venous Anastomosis

For Tetralogy of Fallot In tetralogy of Fallot the venous blood is being shunted from a hard working right ventricle into the left ventricle, aorta, and systemic system The systemic system and heart, therefore, have an overload of viscid unsaturated blood The hypoxia caused by the unsaturated blood reduces the contractility of the left ventricle and produces a low systolic pressure The overload causes a high diastolic pressure In the pulmonary circulation there is an inadequate blood flow The purpose of the surgical procedure is to divert a portion of the large systemic supply of blood into the pulmonary circulation A Potts-Smith procedure anastomoses the aorta and one of the pulmonary arteries, usually the left The Blalock-Taussig procedure usually anastomoses the subclavian artery and one of the pulmonary arteries

Hypothermic technic similar to that used for cardiotomy for repair of atrial septal defect and pulmonary valvulotomy for pulmonic stenosis is used for these operations Hydration is maintained with 5 per cent dextrose and water for the concentrated blood may thrombose at the site of the operation or in the brain Blood loss should be sparingly replaced, but these patients withstand the operation and anesthesia suprisingly well even with minimal blood replacement

During the clamping of the pulmonary artery, ominous signs are marked bradycardia, widening of the QRS complex and high or low take off of the S-T segment Accompanying this, an abrupt drop in alveolar carbon dioxide tension is frequently noted These findings signify severe hypoxia, most likely caused by a reduction in pulmonary blood flow below the critical level, due either to a contralateral atretic pulmonary artery an increased right to left shunt, or an inadequate right atrial filling However modern surgical treatment makes the Potts Smith and Blalock-Taussig procedures palliative by satisfying the patient s urgent need for improved oxygenation Today, a tetralogy of Fallot is anatomically and physiologically improved by closing the ventricular septal defect and removing the pulmonary obstruction

For Tricuspid Atresia Tricuspid atresia seldom exists as an isolated lesion if it is accompanied by an atrial septal defect, then a successful Blalock or Potts Smith operation can be performed The atrial septal de-

a serious condition, and when it exists, ligation of the patent ductus arteriosus is *not attempted*

In patent ductus arteriosus, if the right ventricular pressure is not above 70 mm of mercury a surgical attempt is made to halt the disease, even though the risk is enhanced when the right ventricular pressure is above 15 mm of mercury The patient is managed best with the benefits of mild hypothermia of about 35° C achieved by leaving him in the ice tub for five to ten minutes By this means, the heart rate is slowed and remains slow during the operation

Excision of Coarctation (Adult Type) of the Aorta (with Anastomosis)

In patients with coarctation of the aorta, the arteries arising between the coarctation and the heart have a high blood pressure while those arising beyond the coarctation have a low blood pressure The pressures in the veins draining these areas are also respectively influenced The surgical procedure is to open the chest free the aorta at the level of the coarctation clamp the aorta above and below the coarctation and suture the cut ends If the cut ends of the aorta cannot be brought together, an arterial graft is used The operation is never done in infants except when the heart shows signs of failure The operation is usually performed when the child is around ten to twelve years of age, that is when a collateral *circulation has developed*

The anesthetic management for excision of coarctation of the aorta is the same as for transection of patent ductus arteriosus Hypothermia offers no advantages in this operation In the older child because of the dilatation of the intercostal arteries during the opening of the chest wall considerable blood loss may occur and it is essential that it be replaced as it is lost Clamping of the aorta may cause a severe rise in blood pressure, more likely to occur when the degree of stenosis is not profound Since cyclopropane increases the bleeding and the hypertension, we use Fluothane and nitrous oxide or nitrous oxide, thiopental (Pentothal) or thiamylal (Surital) and relaxant Release of the clamps by the surgeon may be accompanied by a momentary abrupt hypotension sometimes prevented by a vigorous increase in the blood transfusion rate just prior to the release of the clamps

Following coarctation excision in an infant several days of attentive postoperative care by the pediatric anesthesiologist are essential since secretions may cause atelectasis Tracheal aspiration two or three times a day

Transection of a Vascular Ring

The anesthetic management of an infant or child for transection of a vascular ring can be very difficult if there is marked obstruction to the trachea by the vascular or fibrous ring

The premedication is atropine alone The patient is anesthetized with cyclopropane or ether, and then intubated, however, spontaneous assisted respiration is retained until the thorax is opened at which time, controlled respiration is instituted Because the patient has an obstructive lesion and there may be a chronic hyperdistention of the components of the lungs before compressing the breathing bag the anesthesiologist must allow sufficient time for exhalation through the constricted trachea The application of a slow, small negative pressure, —2 or —3 cm water, on exhalation and the use of the largest possible endotracheal tube are advantageous measures Upon opening the thorax in some of these patients, additional obstruction to respiration can occur due to the swing in the mediastinum

Upon transection of the constricting vascular or fibrous band, the obstruction to respiration may disappear In some instances, however, it may be necessary to insert the endotracheal tube past the tracheal constriction in which case the tube must be left in place for several days postoperatively to maintain a patent airway Constant observation of the patient and frequent aspiration of the tube are imperative until the wall of the trachea has become firm However, much of the obstruction to the airway both during and following the surgery can be avoided by doing a tracheostomy under local anesthesia the day prior to surgery The tracheostomy tube is inserted past the vascular ring and remains in situ several weeks postoperatively

Retrograde Aortography

Retrograde aortography involves rapid retrograde injection of contrast media through either the radial or the carotid artery into the aorta, and serial x-ray examination in two planes at right angles to one another The procedure is particularly useful to demonstrate patent ductus arteriosus coarctation of the aorta or left to-right intracardiac shunts

Management of the anesthesia follows the same pattern as for angiocardiography with the exception that the patient usually is cooled to 33° C thus slowing the circulation and affording improved visualization of the dye in the aorta (Fig 159) Another method of achieving this slowing of

fect is essential to return the systemic venous blood to the left ventricle.

Patients with a combined tricuspid atresia and an atrial septal defect have all the symptoms and complications of patients with a severe tetralogy of Fallot, and the anesthetic management is the same for both operations.

For Transposition of the Great Vessels: In transposition of the great vessels there is a rotation of the arterial trunks. The aorta arises from the right ventricle and the pulmonary artery from the left ventricle; thus nonoxygenated blood enters the systemic system and oxygenated blood enters the pulmonary system. These patients live only a few weeks, dying of cardiac failure. There can be many associated anomalies which permit oxygenated blood to enter the systemic system, and in this case the patient's life is extended. In the so-called corrected transpositions the aorta and pulmonary artery are transposed but they still originate from their proper ventricles, and hypoxia does not occur.

Several types of operations have been devised for correction of this condition, but all carry with them a high mortality rate. One operation interchanges the aorta and pulmonary artery; another reroutes the pulmonary veins into the right atrium and the superior or inferior vena cava into the left atrium (Baffe's operation).

For Transposition of Anomalous Pulmonary Veins: Of the patients operated upon for anomalous pulmonary veins, there are two types: first, those in which only some pulmonary veins empty into the right atrium, constituting a left-to-right shunt, or secondly, those in which all pulmonary veins drain into the right superior vena cava or right atrium, associated with an atrial septal defect.

The surgical procedure for both types is to transpose these pulmonary veins into the left atrium and to close the atrial defect; however, patients with a pulmonary hypertension rarely survive.

In operations for correction of tetralogy of Fallot, tricuspid atresia, transposition of the great vessels, and transposition of anomalous pulmonary veins, the anesthesiologist is anesthetizing extremely ill patients on the border of cardiac failure from severe hypoxia. Even the institution of extracorporeal circulation bears considerable risk as compared to its use in patients with the more benign atrial and ventricular septal defects. We employ the hypothermic anesthetic technic as previously described for atrial septal defect repair.

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Fig 159 An aortogram done under hypothermia outlining the aorta its branches and the patent ductus arteriosus between the aorta and the pulmonary artery

the circulation is to momentarily occlude the pulmonary capillary blood flow, accomplished by application of high positive pressure by bag and mask and compression of the breathing bag This high pressure in the breathing bag is transmitted to the alveoli and is sufficient to occlude the pulmonary blood flow, but such pressure must not be maintained for too long a period of time, since resultant sustained systemic hypotension reduces coronary blood flow

Cerebral Arteriography

The diagnosis of intracranial lesions often is facilitated by x-ray study of the cerebral blood supply The surgeon inserts a needle either blindly

or by means of a small cut down into one or both carotid arteries A test dosage of dye is injected, and if there is no reaction, the total dosage of dye is injected and serial films taken

The management of the anesthesia for cerebral arteriography is similar to that for angiocardiography, using endotracheal technic and nonexplosive anesthetic agents Succinylcholine chloride is given just prior to injection of the dye to prevent movement by the patient during taking of the x rays

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CHAPTER 21

OPERATIONS ON THE HEMIC AND LYMPHATIC SYSTEMS

OPERATIONS ON THE SPLEEN

Splenectomy

Splenectomy, while indicated in splenic rupture or lacerations at times is also performed upon patients with congenital or acquired hemolytic anemia congestive splenomegaly Mediterranean anemia, thrombocytopenic purpura, or other types of splenomegaly

The details of the anesthetic management for a splenectomy depend upon the disease of the particular infant or child For instance a congested massive spleen is often difficult to free from the abdominal cavity, with resultant marked blood loss and, occasionally severe hypotension because of the sudden release of intra abdominal pressure Some disorders, particularly congestive splenomegaly often have accompanying esophageal varices which may readily be ruptured should gastric intubation be attempted

The surgeon s report of the patient s condition and his proposed surgical management are essential information to the anesthesiologist in planning the management of the anesthesia In addition, the hematologist usually has been observing the patient with hemolytic disorders for a long time, so his advice on blood transfusion should be respected With recent splenic ruptures, blood usually must be given rapidly in large quantities, but with hemolytic disorders and chronic anemia it is preferable to give a number of small transfusions over a period of time If platelets are decreased, as in thrombocytopenic purpura fresh blood or packed red blood cells may be more effective than older or citrated blood Blood should be available

*for all splenectomies, however, many of the patients who have splenecto*mies for acquired hemolytic anemia receive no blood during surgery

One half the standard dosage of sedative drugs and full dosage of scopolamine, according to the patient s weight, are usually administered but the over-all condition of the patient must as always be taken into consideration in this determination

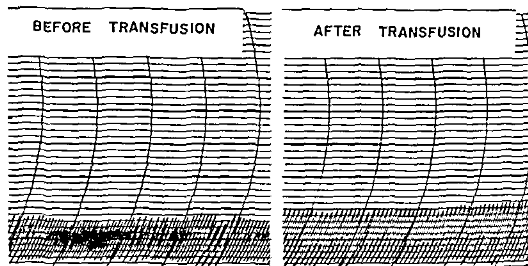


Fig 160 *(Left)* Before transfusion the alveolar CO_2 concentration is 1 8 per cent *(Right)* After transfusion there is an elevation of the end expiratory CO_2 concentra *tion to 2 0 per cent*

Cyclopropane anesthesia is established and the intravenous needles in serted The patient is then intubated with or without the aid of relaxants Either assisted or controlled breathing manually or mechanically regu lated may be used during the maintenance of anesthesia Seldom is it deemed advisable or necessary to administer ether, even on the theory that it causes splenic contraction for many of these hemolytic spleens are so fibrotic that they cannot under any circumstances contract to a sig nificant degree Another very satisfactory combination of anesthetic agents is a small amount of intravenous thiobarbiturate and nitrous oxide then the patient is intubated with the aid of succinylcholine chloride Continu ous or intermittent succinylcholine chloride or d tubocurarine provides ex cellent muscle relaxation during the surgery

In some patients with chronic anemia the continuous alveolar carbon dioxide analysis shows a low alveolar carbon dioxide which becomes elevated following the blood transfusion (Fig 160)

By positioning the patient in slight reverse Trendelenburg position and sloping the table a little lower on the right side than on the left surgery

will be facilitated for this results in both the intestines and the spleen dropping away from the diaphragm, thereby making the pedicle of the spleen more accessible

Postoperatively the anesthesiologist should be alert for signs of left-sided pneumothorax, and for cardiovascular collapse from continued hemorrhages

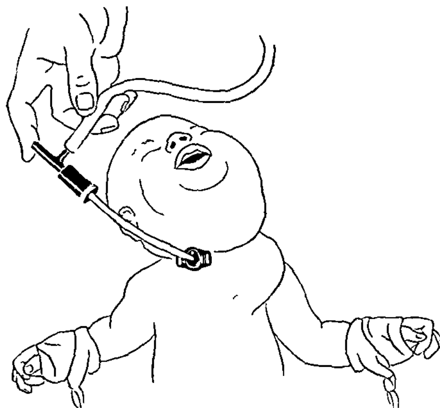


Fig 161 Diagram of a patient with a large cervical cystic hygroma showing the Ayre s T tube technic A preliminary tracheostomy was performed under local anesthesia since the tumor invaded the air passages

OPERATIONS ON THE LYMPHATIC CHANNELS

Excision of Lymphangiomas

Lymphangiomas are multilocular cysts which have their origin in the lymphatic channels The commonest site is in the cervical region where they are identified as cystic hygromas being occasionally associated with hemangiomatous elements Lymphangiomas can occur, however in many other parts of the body

A preoperative tracheostomy is advisable in those patients wherein the patency of the upper airway may be threatened by either the tumor or the surgical procedure (Fig 161) for an airway of minimal or borderline

patency may be entirely occluded following induction of anesthesia Even small amounts of sedative drugs should be omitted from the premedication in these patients because of the ever-present danger of respiratory obstruction

These tumors are most frequently removed at an early age, since they are unsightly and interfere with activity Some of the large hygromas invade the cervical tissues and cannot readily be shelled out and preparations must be made for extensive dissection with considerable oozing

For removal of a large cervical cystic hygroma in a patient without respiratory obstruction, he is anesthetized with cyclopropane and intubated, thereby removing the anesthesiologist from the surgical field and providing a means of ventilatory control should the pleura be inadvertently entered

Another anesthetic method is to give intravenously a small amount of thiopental (Pentothal) or thiamylal (Surital), followed by the administration of succinylcholine chloride intravenously, and then intubation Anesthesia can be maintained with nitrous oxide

Postoperatively, the chief concern of the anesthesiologist is, of course, the maintenance of a patent airway Since many conditions, notably wound edema, fluid collections, and subglottic laryngeal edema, may supervene fastidious postoperative management is instrumental to the safety of the patient Minor degrees of respiratory obstruction may be ameliorated by placing the patient in a cold moist atmosphere In addition, scissors should be available to sever the bandages or the sutures should respiratory obstruction occur Endotracheal equipment and an emergency tracheostomy set must remain at the bedside until the critical airway period has passed

Excision of Hemangiomas

Patients with hemangiomas are managed anesthetically in a manner similar to patients with lymphangiomas, but with an extensive hemangiomatous lesion (Fig 162) several operations may be required, during each of which a portion of the tumor is removed and the area is skin-grafted Blood transfusion may be necessary to combat anemia frequently seen in these patients A bleeding tendency from a thrombocytopenia may also develop since the thrombocytes may adhere to the walls of the hemangioma Any evidence of respiratory obstruction in a patient with several hemangiomas on the surface of the body should alert the anesthesiologist to the possibility of hemangiomas in the mouth larynx, trachea bronchi,

and lungs These hidden lesions may rupture and flood the respiratory passages

Thoracic Duct Operations

Following intrathoracic surgery or chest injury where the thoracic duct has been severed, or as a result of pressure of lymph nodes or neoplasms on the left subclavian vein, a massive chylothorax can occur



Fig 162 An extensive hemangiomatous lesion occupying a considerable part of the thorax and left upper limb Anesthesia is maintained with the infant circle absorption technic and the heart is monitored with an esophageal stethoscope and blood pressure cuff A cut-down in the saphenous vein at the ankle is used to replace the large blood loss during the surgery

In preparation for a thoracic duct operation, the patient is generally on a low fat, high protein diet to decrease the amount of chyle, but a high caloric intake is maintained and in some patients the daily required dose of vitamins especially the fat-soluble vitamins A and D, is administered

In most instances, anastomosis of the severed duct is a difficult procedure but an attempt is made to find the defect and close it The anesthetic management is the same as the technic described for pulmonary lobectomy (See p 304)

Excision of Lymphosarcoma

Relatively rare among malignant tumors of childhood lymphosarcoma may involve the entire lymphatic tissue of the body including the tonsils lymph glands, spleen gastrointestinal tract bone marrow and liver A chest film may reveal mediastinal involvement and strongly suggest the possibility of tracheal and bronchial obstruction a persistent cough further suggests this possibility Pleural effusion and metastases in the ribs may result from intrathoracic lymphosarcoma The blood is often involved after the disease is well advanced with the consequent picture of anemia thrombocytopenia, and bleeding tendency

There may be considerable unsuspected mediastinal involvement for these rapidly growing malignancies may have reached serious proportions without the patient showing any cachectic or anemic effects When there is mediastinal involvement general anesthesia may be extremely hazardous for anesthetic agents and relaxants may cause complete irremediable bilateral bronchial obstruction for excisional biopsy or for tracheostomy in these patients local anesthesia is safer than general Before the more extensive surgical procedure of removal of the intrathoracic tumor is undertaken both the surgeon and the anesthesiologist should consider the serious danger of bronchial obstruction under general anesthesia

These lymphosarcomatic patients frequently exhibit a hemorrhagic diathesis and anemia and a considerable quantity of blood should be available for prompt replacement as it is lost during surgery

If an attempt has been made to excise a mediastinal lymphosarcoma then postoperatively the patient should be observed attentively for signs of respiratory obstruction Application of a cold moist atmosphere reduces the postoperative edema of the air passages

CHAPTER 22

OPERATIONS ON THE DIGESTIVE SYSTEM

The operations on the digestive system herein discussed include those on the entire digestive tract associated organs, and abdominal wall, which contains most of the alimentary tract There is no simple formula applicable to the anesthetic management of the many different operations on the digestive system since the patients presented for surgery represent the entire range in age risk, and difficulty of pediatric anesthesiology

OPERATIONS ON THE MOUTH

Incision and Drainage of Abscesses

Incision and drainage of an abscess of the floor of the mouth or buccal surface of the cheek is rare The purpose of the surgery is to incise the abscess widely so that the pus can escape Premedication is either atropine or scopolamine Even in these relatively simple operations the usual precautions such as preparing for anesthesia with precordial stethoscope blood pressure cuff plethysmograph cardiac monitor, and endotracheal equipment are observed

Cyclopropane or Fluothane anesthesia with nonrebreathing or absorption in circuit technic and nasal intubation with or without the aid of succinylcholine chloride relaxation provides the greatest safety for the patient If there is considerable swelling of the tissues of the mouth, the patient's cords are sprayed with local anesthetic and he is intubated awake The pharynx is packed with dry paraffin gauze to keep pus out of the stomach

Excision of Lymphosarcoma

Relatively rare among malignant tumors of childhood, lymphosarcoma may involve the entire lymphatic tissue of the body including the tonsils lymph glands spleen gastrointestinal tract, bone marrow and liver A chest film may reveal mediastinal involvement and strongly suggest the possibility of tracheal and bronchial obstruction a persistent cough further suggests this possibility Pleural effusion and metastases in the ribs may result from intrathoracic lymphosarcoma. The blood is often involved after the disease is well advanced, with the consequent picture of anemia, thrombocytopenia, and bleeding tendency

There may be considerable unsuspected mediastinal involvement, for these rapidly growing malignancies may have reached serious proportions without the patient showing any cachectic or anemic effects When there is mediastinal involvement, general anesthesia may be extremely hazardous for anesthetic agents and relaxants may cause complete irremediable bilateral bronchial obstruction for excisional biopsy or for tracheostomy in these patients local anesthesia is safer than general. Before the more extensive surgical procedure of removal of the intrathoracic tumor is undertaken, both the surgeon and the anesthesiologist should consider the serious danger of bronchial obstruction under general anesthesia.

These lymphosarcomatic patients frequently exhibit a hemorrhagic diathesis and anemia, and a considerable quantity of blood should be available for prompt replacement as it is lost during surgery

If an attempt has been made to excise a mediastinal lymphosarcoma, then postoperatively the patient should be observed attentively for signs of respiratory obstruction. Application of a cold, moist atmosphere reduces the postoperative edema of the air passages

the mouth and pharynx are aspirated, and the endotracheal and gastric tubes are removed

Postoperatively, these patients require constant observation If swelling is present, immediate placement in a cold, moist atmosphere will lessen the degree of postoperative edema In the more severely obstructed patient a tracheostomy set should be at his bedside He should remain in the hospital until all danger of obstruction to the airway from swelling is past

OPERATIONS ON THE LIP

Cheiloplasty (Cleft Lip Repair)

The surgery on this unilateral or bilateral deformity usually is done soon after birth Early closure of the cleft retracts the protruding premaxilla, improves the infant s feeding ability, helps to placate the emotionally disturbed parents, and suspends development of a possibly emotionally disturbed child In order to reduce the mortality and morbidity in such young infants some surgeons prefer to repair only one side of a bilateral cleft lip at a time

Premedication usually is scopolamine alone unless the patient is an older child who has undergone previous operations, in which case a sedative is added In disturbed infants or children, rectal barbiturates are administered

Most anesthesiologists prefer the endotracheal technic A firm, thin-walled tube of as large a bore as possible or a rubber tube reinforced with an incorporated wire coil is less likely to kink The attached Magill angle piece is pointed caudad since the surgeon sits at the head of the table The infant may be anesthetized with cyclopropane, using the infant absorption in circuit or nonrebreathing technic Intubation may be with or without the aid of succinylcholine chloride relaxation Intubation is often difficult when there is first, limited movement of the mandible, second, marked protrusion of the maxilla and premaxilla complicating the exposure of the glottis and third the laryngoscope lumen is blocked by tissue, which occurs in bilateral or in right-sided clefts The last-mentioned complication can be overcome by plugging the cleft with a gauze pack It is only by preanesthetic analysis and evaluation of these handicaps to intubation that the anesthesiologist can intelligently select his anesthetic agent and technic The inexperienced anesthesiologist will be well advised

Postoperatively, these patients are kept in the lateral Trendelenburg position to facilitate drainage of the pus and blood from the mouth

Suture of Laceration

Since an infant or child presented for suturing of a lacerated mouth generally is an "accident" case the anesthesiologist should be mindful of certain facts applicable in most "accident" cases The frightened parents *rush the frightened child to the surgeon and hospital* A marked emotional atmosphere of urgency is created, but this atmosphere should not stampede the anesthesiologist into hasty cursory preparations for anesthesia. He should assume, first, that the stomach may contain food or blood and second that there may have been a copious loss of blood. The hematocrit or hemoglobin, blood pressure and pulse rate should be taken On rare occasions, the necessity of a blood transfusion prior to surgery may have to be considered.

If the surgery is urgent because of continued bleeding then atropine or scopolamine is sufficient for premedication A large-bore aspirator should be immediately at hand and a needle inserted into the vein before the patient is anesthetized

The patient should be anesthetized very quickly Probably the most rapid technic is to give a small amount of intravenous thiopental (Pentothal) or thiamylal (Surital) followed immediately by a sufficient dose of succinylcholine chloride to ensure muscle relaxation and easier intubation. Some anesthesiologists insert the endotracheal tube under local anesthesia because they feel that this avoids the danger of the aspiration of blood or food.

A cuffed stomach tube is passed and the cuff inflated to prevent regurgitation of stomach contents Gastric aspiration is performed.

The anesthesia is maintained with a minimum amount of inhalation agent to ensure an early postoperative return of consciousness A nonrebreathing or absorption technic is used. With the anesthesiologist removed from the operative site, the surgeon can then proceed with adequate time to perform this important reconstructive surgery As in cleft palate operations, a retractor suture may be put in the tongue for safer postoperative treatment.

At the completion of the surgery the anesthesiologist should leave the endotracheal tube in place until the patient is demanding its removal At this stage the patient is turned in the lateral Trendelenburg position

At the termination of surgery, a suture is placed in the tongue for facilitating tongue retraction in the recovery period When the infant is almost awake he is extubated



Fig 164 Infant has Pierre Robin syndrome with receding lower jaw glossoptosis and small epiglottis

Because the patient is generally a very young infant a small degree of laryngeal edema from the intubation can cause considerable obstruction to respiration The infant, therefore, should be put in a cold, moist atmosphere if there are signs of upper respiratory obstruction Because of the immobilization of the upper lip and the frequent presence of cleft palate, the infant cannot suck a nipple so he must be fed with a feeder The liquid formula dropped onto the base of the tongue is swallowed by the infant

Operation for Micrognathia and Glossoptosis (Pierre-Robin Syndrome)

In infants with a Pierre-Robin syndrome (Fig 164) the tongue may be sutured to the alveolar ridge of the mandible to relieve the respiratory obstruction The infant is kept preoperatively and postoperatively in the

to use an anesthetic technic such as open drop ether, which will keep the patient breathing and allow a longer time for intubation Following intubation, the angle piece of the endotracheal tube is strapped with adhesive tape close to the chin in the center of the lower lip The best angle piece is one with a port for occasional tracheal aspiration during the surgery



Fig 163 Infant prepared for repair of a cleft lip illustrating the T tube technic

Anesthesia may be maintained with either a combination of nitrous oxide and subcutaneous or intramuscular succinylcholine chloride or nitrous oxide and light ether The anesthetic technic may be nonrebreathing infant absorption in circuit or T-tube (Fig 163) Trendelenburg position and a throat pack prevent blood from entering the trachea This pack should always be attached firmly to a suture brought to the outside of the mouth Blood transfusion during surgery is not customary unless the infant is anemic or the blood loss excessive as it might be in repair of a bilateral cleft lip Conservation of body heat is essential especially in prolonged procedures such as bilateral cleft lip repair

cyclopropane is added until satisfactory analgesia is established, when the oral mask is removed and a pack is carefully inserted in the mouth, ensuring that there is no encroachment on the nasal airway which would prevent the child from breathing through his nose Most of the gases are blown off through the exhalation valve in the nasal mask



Fig 165 Child breathing nitrous oxide trichlorethylene and oxygen through the McKesson nasal mask preparatory to having his teeth extracted The oral mask has been removed The mouth gag is in place The oral pack will be positioned later

Should the throat packing become saturated with blood, it is removed immediately and replaced with a fresh one, since soggy saturated packs can easily be lost or left in the pharynx later causing dangerous respiratory obstruction To prevent blood from running down the throat, a pack is held firmly in the wound after the extraction The anesthetic gases are turned off and oxygen is administered for several minutes to avoid the danger of diffusion hypoxia The child awakens quickly, provided the trichlorethylene or Fluothane concentration has been kept at a minimum

Another excellent method is to give intravenously small intermittent doses of a thiobarbiturate Very light barbiturate anesthesia is maintained

prone position for minimal airway obstruction Only atropine or scopolamine is given for preanesthetic medication

Intubation is often very difficult because of the small receding mandible, glossoptosis, and small epiglottis Because of this intubation difficulty and the possibility of early respiratory obstruction, the infant is intubated awake Once the crucial intubation is accomplished, a variety of agents and technics can be used for the maintenance of anesthesia The usual supportive care for the newborn infant during and following surgery is taken A laryngeal edema following extubation should be treated immediately On account of the threat to the patency of the airway by the lesion, the infant requires constant vigilance postoperatively by the nurse

OPERATIONS ON THE TONGUE

Suture of Laceration

Anesthetic management for suture of a lacerated tongue (glossorrhaphy) is similar to that described for suture of a lacerated mouth (p 340)

OPERATIONS ON THE TEETH AND GUMS

Incision of Alveolar Abscess or Infected Cyst, and Excision of Adamantinoma

For incision of alveolar abscess or infected cyst or excision of adamantinoma in children, an endotracheal technic with cyclopropane is suggested

Extraction of Teeth

Extraction of teeth is usually a very brief operation in children Even though most of the patients are ambulatory, a careful preanesthetic evaluation and preparation are essential since the anesthesiologist may be the only physician in close contact with the patient

For the extraction of deciduous teeth or for brief procedures as premedication a small dose of rectal or oral barbiturate and intramuscular scopolamine are given one hour before the dental extraction

The child is placed on the dental chair or operating room table in the supine position, and blood pressure cuff and precordial stethoscope are applied After placing the mouth gag anesthesia is induced with nitrous oxide and oxygen through nasal and oral masks (Fig 165) The child is encouraged to breathe through his nose Trichlorethylene, Fluothane, or

pending on the preference of the pedodontist The authors favor the direct less traumatic oral route

Anesthesia is maintained with nitrous oxide and small increments of trichlorethylene by the nonrebreathing technic (Fig 166), or Fluothane

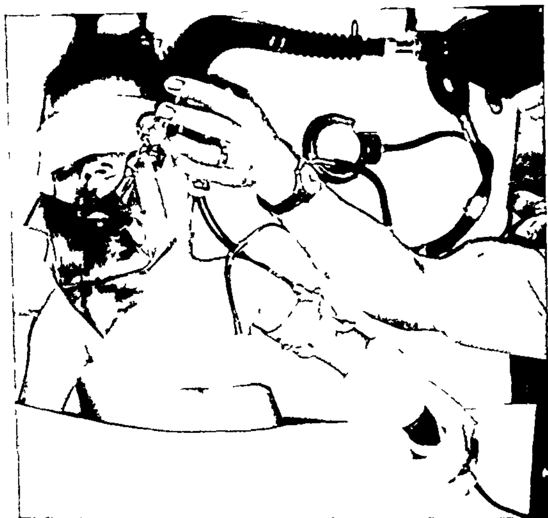


Fig 166 Nitrous oxide and trichlorethylene are being employed for a dental filling A rubber dam is attached to the teeth In a vein in the left hand is an intravenous needle for administration of muscle relaxant

by infant circle filter technic Minimal succinylcholine chloride by continuous drip is administered to relax the jaw and facilitate the work of the pedodontist

A dental rubber dam isolates the working area from the rest of the mouth preventing debris and foreign material from falling into the throat At the end of the operation, all remaining material and secretions are aspirated from the pharynx, and the endotracheal tube is removed Since

during the extraction Although the child may move his head slightly, the respiratory and cardiovascular systems will not be depressed, nor will there be prolonged laryngospasm with this method

The child, following the operative procedure, is placed on the stretcher in the lateral Trendelenburg position and taken to the recovery room where he usually expectorates blood and saliva for a short time, but soon is ambulatory and may leave the hospital within a few hours

If the extraction is more extensive, as in older children with impacted teeth or multiple extractions an endotracheal tube is inserted to maintain a clear airway and provide the surgeon with satisfactory operative conditions In such a patient a needle is placed in a vein, and the patient is anesthetized with a small intravenous dose of thiobarbiturate or with cyclopropane, and succinylcholine chloride if muscle relaxation is necessary for intubation Following surgery the patient remains under observation until all danger of subglottic edema has disappeared

Patients with some crippling disorder such as congenital heart disease, nephritis diabetes, or rheumatic fever should be admitted to the hospital for extraction of teeth and a scrupulous evaluation made of the disease These children, premedicated with a sedative and scopolamine, are anesthetized with cyclopropane and a small amount of succinylcholine chloride is given intravenously or intramuscularly for intubation In addition to monitoring the cardiovascular system with a precordial stethoscope, another monitor such as an electrocardiograph is used The patient is kept in the hospital at least 24 hours postoperatively for observation

Repair of Teeth

Children with dental caries may have some handicap necessitating general anesthesia during the dental procedure For instance, a large number of these patients have cerebral palsy and may be either mentally disturbed or have motor incoordination others are emotionally disturbed children who do not tolerate dental care while awake

These children are admitted to the hospital and the routine history, physical examination and blood and urine tests are obtained They are given full sedative and scopolamine premedication

A nonexplosive method of anesthesia is employed since the dental drill against the teeth causes sparks After applying a precordial stethoscope and blood pressure cuff anesthesia is induced with an intravenous, ultra short acting thiobarbiturate and with the aid of intravenous succinylcholine chloride either orotracheal or nasotracheal intubation is performed, de

surgical field The airway is often improved by placing a sand pillow under the shoulders and extending the head, thus preventing acute angulation of the endotracheal tube in the back of the pharynx

Blood loss may be copious and difficult to control, and adequate blood should be supplied by transfusion during the operative period Slight Trendelenburg position and frequent aspiration of the pharynx will keep the blood out of the stomach and tracheobronchial tree

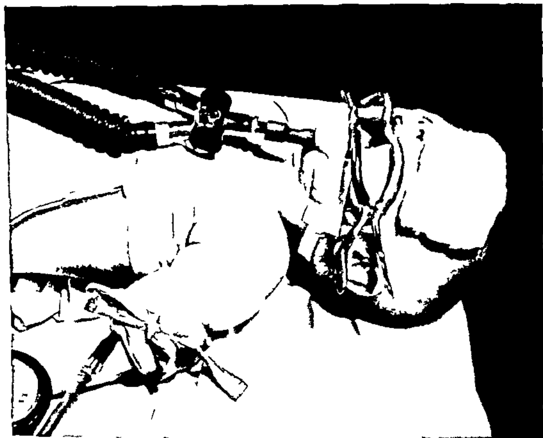


Fig 167 Child prepared for repair of a cleft palate The surgeon sits at the head of the operating table and the anesthesiologist at the left side of the patient

At completion of surgery, the surgeon usually puts a retractor suture through the tongue, so that postoperatively the nurse can clear the airway by pulling on the retractor suture which pulls the tongue forward The patient should be almost awake at the end of surgery All blood should be aspirated out of the pharynx, and a thorough search made for throat packs after which the patient is extubated and placed on his side in Trendelenburg position If tolerated by the patient an oropharyngeal airway is inserted This must be done gently to avoid injury to the repaired palate

The infant or child is placed on the carrier in the lateral position and re-

these operations often take two to three hours, postoperatively the patient is placed in cold, moist atmosphere to minimize laryngeal edema If no complications occur, the patient is discharged from hospital the day following repair of the teeth

OPERATIONS ON THE PALATE AND UVULA

Palatoplasty (Cleft Palate Repair)

Palatoplasty usually is performed on infants six months to two years of age, some of whom return for further stages of palate surgery and therefore may develop a phobia for anesthesia and surgery If the palatoplasty is postponed until the child is over two years of age, he may have a feeling of inferiority and introversion as a result of his cleft palate, impaired speech and hearing difficulties Speech training the development of aptitudes and the establishment of a friendship with the surgeon and anesthesiologist help create a feeling of security in such a child

Premedication with a sedative and 'drying' agent or with a rectal barbiturate makes the induction of anesthesia more pleasant Another measure to prevent some of the phobia for anesthesia is the insertion of an 18 gauge styletted intravenous needle when the child is under inhalation anesthesia In infants a cut down is done in the saphenous vein at the ankle The patient is anesthetized with cyclopropane and intubated with or without succinylcholine chloride as a relaxant, some surgeons preferring nasal intubation, and others oral If oral intubation is used, a small pack in the posterior pharynx pushes the tube forward away from the palate Since the surgeon sits at the head of the table, the tube is placed over the center or side of the tongue with the Magill connector pointing caudad the endotracheal tube being strapped firmly to the chin (Fig 167) It is important to keep the angle piece close to the chin so that it will not interfere with the surgeon s hands If nasal intubation is used, the angle piece points laterally from the nostril

Many different anesthetic agents can be used for maintenance Nitrous oxide with small increments of ether or intermittent or continuous succinylcholine chloride permit the use of epinephrine by the surgeon In some instances, to minimize bleeding we have employed Fluothane, but this precludes the use of epinephrine The technic may be nonrebreathing valvular, infant circle filter or T-tube Before commencement of the operation, the anesthesiologist should be positive that the airway is patent, noting in particular the absence of inadvertent bronchial intubation for later it is difficult to adjust the equipment without threatening the sterility of the

The patient is placed in steep Trendelenburg position and anesthetized very lightly with ether or cyclopropane, the mask is removed from the face the mouth is opened, and the abscess aspirated with a needle on a syringe to confirm the diagnosis At first, a small incision is made in the abscess to allow a gradual escape of pus, then later the incision is enlarged The patient is almost immediately awake following the operation and has full control of his protective pharyngeal and laryngeal reflexes

Removal of Branchial Cleft Cyst or Fistula

A branchial cleft cyst or fistula is usually formed from a remnant of a right or left branch of the second or third branchial cleft and lies anterior to the sternomastoid muscle Occasionally, the fistula will track up to the tonsillar area To prevent recurrence the surgeon attempts to remove the fistulous tract or cyst in its entirety

The operation is usually performed when the child is close to adolescence since the lesion may not become obvious until then Our standard premedication is given because there is no obstructed respiration

Although a wide selection of anesthetic agents and technics may be used for this procedure, most of them incorporate endotracheal intubation The patient can be anesthetized with an intravenous thiobarbiturate, given succinylcholine chloride, and intubated Following intubation the patient's shoulders should be placed on a sand pillow to extend the head and give the best exposure of the neck to the surgeon Seldom is blood loss extensive enough to require transfusion The child is extubated at the end of the surgery and postoperative problems rarely arise

Tonsillectomy and Adenoidectomy

Children with chronic infection in their tonsils and adenoids may show resultant malnutrition anemia otitis media or degrees of deafness Thin, narrow-faced children may have chronic respiratory obstruction and mouth breathing

The daily occurrence of this operation should not encourage poor preparation, but rather there should be done a history, physical examination hemogram, bleeding and clotting time and urinalysis Severe anemia should be corrected if possible by iron therapy and diet before surgery

Preanesthetic psychotherapy is important in soothing the child and in reducing the amount of preanesthetic sedation to be given Admission of the child to the hospital the night prior to operation is very beneficial allowing him an opportunity to become acquainted with his strange new surroundings and with other children the nurses and anesthesiologist.

turned to the recovery room, where postanesthetic care is concerned primarily with maintenance of a dry, unobstructed airway until the patient is accustomed to the new architecture of his mouth If the surgery has been prolonged, it may be advisable to put the infant or child into cold, moist atmosphere until all danger of post intubation subglottic edema has disappeared Intravenous fluids may be necessary, since his sore mouth makes the child averse to drinking or swallowing Any nausea or vomiting should be controlled with an antihistaminic drug given intramuscularly or as a rectal suppository Postoperative hemorrhage must be contemplated

Suture of Lacerated Palate

The anesthetic management for suturing a laceration of the palate is the same as that described for suturing a laceration in the mouth (p 340)

OPERATIONS ON THE SALIVARY GLANDS AND DUCTS

Exploration of Gland and Duct and Excision of Salivary Gland (Ranula, Mixed Tumor)

The anesthetic management for these operations is similar to that for any other major intraoral operation, but the length of the procedure makes intubation mandatory (See Palatoplasty,' p 348)

OPERATIONS ON THE PHARYNX, ADENOIDS, AND TONSILS

Incision of Peritonsillar Abscess and Retropharyngeal Abscess

In spite of antibiotics, on rare occasions it still is necessary to anesthetize a patient for incision of a peritonsillar or retropharyngeal abscess, often following a bout of acute tonsillitis These infants and children are suffering from the effects of infection and inadequate food and fluid intake for several days The degree of respiratory obstruction from retropharyngeal or peritonsillar abscess may be serious since the anterior protrusion of the posterior pharyngeal wall often blocks the nasal airway It may even push the palate forward so that it impinges on the tongue blocking the oral airway also Further, these patients, on account of the presence of infection often have a hyperactive laryngeal reflex The likelihood of a fatal total respiratory obstruction occurring during anesthesia has accounted for many surgeons incising the abscess without any anesthesia

If there are no signs of preanesthetic respiratory obstruction an anesthetic can be administered for the patient s comfort Only atropine or scopolamine should be given as premedication

Another excellent method of anesthesia for tonsillectomy is the use of the Barton mouth gag, a Davis gag modified by an added tunnel along the tongue depressor to house an endotracheal tube In this case, a longer endotracheal tube is inserted drawn up retrograde through the tunnel, after which the connector and circle absorber are attached to the tube (Fig 169)

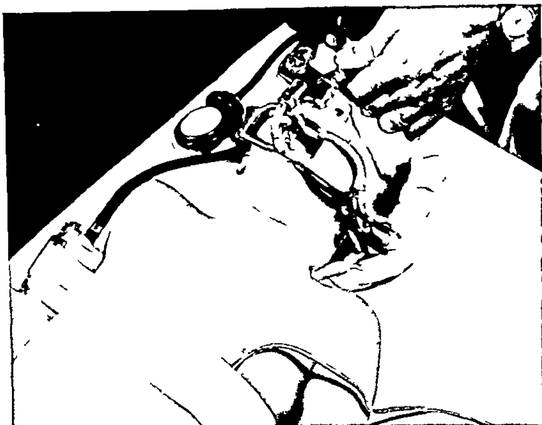


Fig 168 Child undergoing a tonsillectomy The endotracheal tube is well over to the right corner of the mouth so that it will not interfere with the surgeon as he removes the left tonsil

Still another anesthetic technic for tonsillectomy is open drop ether followed by ether insufflation through a mouth hook With this technic, the patency of the airway is largely the responsibility of the surgeon

Occasionally the surgeon, because of uncontrolled hemorrhage in the adenoid region will insert a postnasal pack which is kept in place by a suture, the ends being brought out through the nostril and firmly secured to a pack or rubber tubing Another method has one arm of the suture pass out through the nostril and the other through the mouth then tied firmly together However the arm of the ligature which passes out through the nostril should also be secured to either a piece of rubber or a pack

Such prior admission also prevents the child from obtaining food or milk the morning of operation

Our usual premedication consists of secobarbital or pentobarbital by rectal suppository administered one and one-half hours, and scopolamine hypodermically one hour, prior to operation There are, however, a host of other preanesthetic medications which are very satisfactory

As in all other cases, the precordial stethoscope, blood pressure cuff, and finger plethysmograph are used

Children are often quickly induced with nitrous oxide and Fluothane or a high concentration of cyclopropane, while their attention is held by stories or conversation for these few seconds until consciousness is lost Older children may be induced with a small amount of thiobarbiturate given intravenously through a styletted needle which has been inserted beforehand under local anesthesia

A mixture of nitrous oxide and Fluothane has recently become the choice of anesthetic agents for tonsillectomy in our institution Seemingly, the bleeding is reduced even in the absence of hypotension The anesthesia is induced quickly with about 2 per cent Fluothane in a combination of 2 liters of nitrous oxide and 2 liters of oxygen, the blood pressure must be taken frequently during induction The anesthesiologist experienced in the use of Fluothane can effect a considerable economy by using reduced flows of all of these agents

Large tonsils and adenoids may obstruct the child early in the induction period An oropharyngeal airway partially inserted in a very light plane of anesthesia or a well-lubricated nasopharyngeal tube may be needed to maintain unobstructed respiration Should a laryngospasm occur during induction, succinylcholine chloride 0 5 to 1 mg/kg of body weight is injected intramuscularly or intravenously and then the intubation is completed Early controlled respiration reduces the incidence of laryngospasm, soon brings on apnea reduces tone in the muscles and facilitates intubation

Following intubation the eyes are protected with 5 per cent boric acid ointment and a moist cotton pad

After insertion of the mouth gag the tube is moved over to the side of the throat opposite the surgery (Fig 168) Some surgeons prefer the angle piece placed laterally between the mouth gag and the teeth out of the way of the shaft of the tonsillotome

The Fluothane technic is recommended only for anesthesiologists who recognize the necessity of and practice constant monitoring of the patient

secretions and blood At times, a small amount of secretion may collect in the lower cheek, and if so, is removed with the aspirator (Fig 170) The patient is placed on the carrier in the lateral position, with the head extended and a free airway established A tie is passed around the carrier and the patient just over his pelvis to keep him from moving



Fig 170 Child in the lateral Trendelenburg position during the immediate recovery period following tonsillectomy Secretions are being aspirated out of the dependent cheek Bag and mask are ready should artificial ventilation of the lungs be necessary

The anesthesiologist transfers the patient to a recovery room nurse after placing him on his side in bed in moderate Trendelenburg position to facilitate proper drainage of secretions blood, and vomitus The anesthesiologist during his postoperative rounds treats immediately any suspected laryngeal edema with cold moist atmosphere He or the nurse reports forthwith to the surgeon any continued trickle of blood or any massive emesis of blood for the patient may continue to swallow large amounts of blood from continuously oozing blood vessels A blood transfusion may be required immediately even prior to ligation of a bleeding vessel which

outside of the nostril, since the child may bite through the mouth ligature and the postnasal pack may become detached and be aspirated The mouth must also be kept open, when a postnasal pack is in place, to allow the child a clear airway This is done until he is fully awake by using a short airway between the teeth The size of the postnasal pack is also important for a large pack in a small infant may push the soft palate forward to impinge on the tongue and occlude the only remaining airway the oral airway

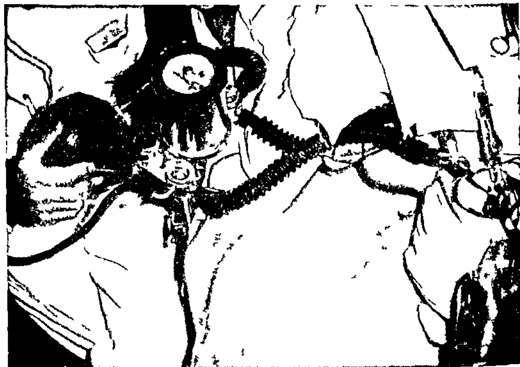


Fig 169 Patient undergoing a tonsillectomy in which the Barton mouth gag is employed The endotracheal tube fits into the tunnel on the tongue depressor part of the gag The surgeon is seated at the head of the table The anesthesiologist is using a Heidbrink infant circle filter

Rarely is any supportive therapy required during tonsillectomy but occasionally a large amount of blood lost during operation must be replaced Very rarely is ligation of the carotid artery necessary

At the end of the operation the child is oxygenated and turned on his side in deeper Trendelenburg position and when anesthesia is very light the endotracheal tube is removed gently This avoids some of the laryngospasm frequently seen on emergence from cyclopropane anesthesia The mouth gag is removed and the airway maintained by holding the head extended the jaw forward and the mouth open to facilitate the outward flow of

nasal catheter Deep anesthesia is important, since the movement or tightening on the esophagoscope may rupture this comparatively delicate structure, the esophagus, with subsequent mediastinitis



Fig 171 The surgeon is about to pass the esophagoscope The patient is under endotracheal anesthesia and his muscles are completely relaxed with succinylcholine chloride The endotracheal tube comes out of the left corner of the mouth and the esophagoscope is introduced at the right side

With no endotracheal tube in place the anesthesiologist must be ever alert to detect any obstruction to respiration which the endoscopist may cause by anterior pressure of his esophagoscope on the soft posterior wall of the trachea, devoid of the supporting aid of cartilaginous rings In addition any slowing of the heart rate immediately apparent through the precordial stethoscope or other cardiac monitor demands better oxygenation, relief of the obstruction or decrease in the concentration of the anesthetic agent

With this deep ether technic, when the esophagoscope is removed,

usually can be controlled temporarily with sustained pressure The transfused patient can be more safely anesthetized and intubated for the second operation

OPERATIONS ON THE ESOPHAGUS

Esophagoscopy

Patients presented for esophagoscopy most commonly have either congenital or acquired esophageal stricture, or an esophageal foreign body Children with severe stricture from swallowing caustics are often on a fluid diet and may show considerable weight loss, debility, and anemia from inadequate food intake The swallowed caustic also may have caused a concomitant injury to the larynx An esophageal foreign body may cause pain on swallowing which interferes with adequate nourishment, so that dehydration is a frequent finding preoperatively

Premedication consists of scopolamine or atropine given intramuscularly one half hour before anesthesia

Enough thiobarbiturate to cause unconsciousness is injected intravenously The patient is given a muscle relaxant, usually succinylcholine chloride, and intubated The angle piece of the tube points caudad out of the left corner of the mouth To this is attached a nonrebreathing or absorption in circuit apparatus Anesthesia and relaxation are maintained with nitrous oxide and succinylcholine chloride intravenously, intramuscularly, or subcutaneously Fluothane, trichlorethylene, or cyclopropane may be added All of these agents are severe respiratory depressants, therefore manual or mechanical pulmonary ventilation is mandatory

When the patient is fully relaxed the esophagoscope is readily introduced into the right corner of the mouth by the endoscopist (Fig 171)

The patient's head is lowered and the esophagoscope is advanced (Fig 172) Following biopsy dilatation of the stricture or removal of the foreign body from the esophagus, the esophagoscope is withdrawn and anesthesia discontinued The lungs are inflated with oxygen until the return of adequate spontaneous respiration when the throat is aspirated and the endotracheal tube withdrawn This system of anesthesia affords protection of the airway by an endotracheal tube and also excellent muscle relaxation for the facility of the work of the endoscopist and his assistant

If however, the endoscopist wishes to study esophageal contractions or there is a tracheal lesion, then open drop ether to a deep plane of anesthesia is given The ether anesthesia is continued by a mouth hook or a

possible Also intracranial hemorrhage, intrapulmonary hemorrhage, atelectasis pneumonia of the right upper lobe and imperforate anus jeopardize the recovery

An appropriate period of preoperative preparation in these patients allows time to combat infection with antibiotics and to improve alveolation of the poorly expanded lungs while further pulmonary contamination is minimized by constant drainage of saliva from the upper esophageal pouch The infant is maintained in a semisitting position to avoid reflux of gastric juice through the lower esophageal segment into the lungs Patients with respiratory distress are placed in a warm incubator containing no more than 40 per cent oxygen Isolation technic is essential

Just before the operation, a cut-down is done in an ankle vein to allow for the administration of blood during surgery The surgical treatment consists of a right transthoracic incision with an extrapleural or transpleural exposure of the lesion, ligation of the fistula, if one is present and an end to end esophageal anastomosis Immediately after the completion of the thoracotomy, a temporary gastrostomy is ordinarily performed for feeding purposes, and for later retrograde dilatation of the scarred anastomotic area should it prove necessary

The patient is transported in an incubator to the operating room, previously warmed to 26 7° C, and placed on a mattress containing water heated to 40° C The stethoscope is strapped high on the left chest to avoid the surgical site, a small blood pressure cuff and finger plethysmograph are applied, and the heart is also monitored by an electrocardiograph, using needle electrodes A continuous recording rectal thermometer is inserted The cut-down is tested for patency security, and lack of leakage All secretions and Lipiodol are suctioned from the blind upper pouch through a No 8 French urethral catheter and the catheter left in place

Even though the operation is performed within the first week of life, preanesthetic medication is not omitted because there is very often a pronounced flow of secretions Atropine 0 06 mg (gr 1 1000), given intramuscularly thirty minutes before surgery, is usually sufficient premedication

Two small endotracheal tubes of an outer diameter of 4 6 mm (No 14 French) are placed in aqueous Zephiran Small thin polyethylene catheters ready for aspiration are tested before induction for their ability to pass through the endotracheal tubes and are marked at the endotracheal tube length to indicate where they go beyond its tip

After scrubbing his hands the anesthesiologist removes the endotracheal

oxygen is administered by bag and mask for several minutes The patient is watched until the anesthesia has lightened sufficiently to ensure his safe return to the recovery room

Retrograde esophagoscopy with dilatation of a stricture by rubber dila tors through the gastrostomy is usually done without general anesthesia



Fig 172 The patient s head has been lowered and the esophagoscope is being advanced by the endoscopist

Anastomosis of Esophageal Atresia or Closure of Tracheoesophageal Fistula

The common type of esophageal malformation consists of a blind upper esophageal pouch and a lower esophageal segment which communicates freely with the trachea above and the stomach below Other types of con genital anomalies of the esophagus include esophageal atresia of either the upper or lower segment or both with or without tracheoesophageal fistula A more detailed description of the evaluation of these conditions is set forth in Chapter 7 (p 136) Other anomalies such as congenital heart disease and agenesis of the kidneys when associated with esophageal atresia or tracheoesophageal fistula may make survival of the patient im

Another serious complication is kinking of the bronchus Since the cartilages surrounding the bronchi of the newborn are soft, retraction of the lung by the surgeon may cause occlusion or kinking of a primary bronchus and resultant hypoxia A pause in surgery with inflation of the lungs and replacement of the retractor in a different position will generally remedy the situation

It is best to supply small increments of blood to replace the estimated loss, done slowly with a syringe through a three way stopcock The color of the patient and warmth of his extremities are usually excellent indications of the adequacy of blood replacement, as infants turn slightly paler when the blood volume is decreased and slightly redder when too much blood is administered

Occasionally during the procedure, the anesthesiologist should allow the infant to breathe spontaneously, since surgical manipulation may cause a contralateral pneumothorax not evident if controlled breathing is maintained throughout The diagnosis of contralateral pneumothorax can be made by (1) the absence of tidal air movements in the breathing bag although the thorax is expanding with inspiration and contracting with expiration, (2) the absence of breath sounds during spontaneous respiration and (3) x rays of the chest At the end of surgery the pneumothorax may be reduced by withdrawing air with syringe and needle, attached to a three-way stopcock and the breath sounds will reappear

A nasoesophageal catheter helps the surgeon identify the blind upper pouch and also empties the stomach after it is threaded down through the anastomotic site under direct vision by the surgeon The anastomosis having been completed, the lung is gradually and fully inflated and the chest closed If the transpleural approach is used the surgeon inserts a water-seal drainage

The infant is now placed in the supine position and a gastrostomy is performed, after which a string is tied securely to the end of the nasogastric catheter and the catheter withdrawn through the nose One end of the string is brought out through the nose the other through the gastrostomy opening and the two ends tied together These are later used as guides for the retrograde esophageal dilators

When the respirations are satisfactory, the patient is extubated and soon awake He is returned to the ward in an incubator heated to a temperature of 23 9° to 26 7° C with no more than 40 per cent oxygen and a humidity of 60 per cent

In the first twenty four hours after operation, diligent individual nursing

tubes from the Zephiran washes them thoroughly in running water, and places them in a clean towel A Rovenstine angle piece with a suction port in it is attached to each endotracheal tube

Two methods of induction and intubation are currently in use in our hospital In one, the patient is given 100 per cent oxygen to breathe for one to two minutes then intubated awake In the other, the patient is induced with cyclopropane and intubated

The anesthesiologist should note on the x-ray whether there is gas in the stomach or intestines indicating a fistulous communication between the lungs and stomach If there is no gas succinylcholine chloride can be used If there is a communication, succinylcholine chloride and too powerful ventilation of the lungs during the induction and following intubation should be avoided, since the gas trapped in the stomach can cause greatly restricted diaphragmatic movement and increased abdominal pressure with considerable elevation of the venous pressure Following intubation the patient is postured in the right lateral or semiprone position, with the right *side uppermost*

The anesthetic agent of choice for maintenance is cyclopropane The technic may be nonrebreathing valvular, infant circle filter, or Ayre s T-tube If the T-tube is employed, a small amount of ether may be necessary for induction and maintenance of anesthesia We generally use a nonrebreathing or infant circle filter technic

With the open thorax the indicator of pulmonary ventilation is inflation and deflation of the lungs A slight positive pressure of 2 to 3 cm of water maintained at the end of exhalation will reduce considerably any mediastinal swing This swing is more readily controlled with the infant circle filter than with the T-tube or valve

In some cases a bradycardia will occur from hypoxia or overdose of cyclopropane Regardless of the cause the treatment is the same, the anesthetic gases are emptied from the bag which is then filled quickly with oxygen and the lungs gently inflated until the normal heart rate is restored The occurrence of bradycardia is more frequent when pneumonia or atelectasis is present

The most serious complication is blockage of the endotracheal tube which sometimes occurs in prolonged operations with inadequate intermittent tracheal aspirations Occasionally even an aspirating catheter cannot be forced down the endotracheal tube due to inspissated material but often a wire obturator can be used successfully if this fails, the tube must be removed and the other clean endotracheal tube inserted rapidly

Preanesthetic medication is governed by the condition of the patient. In the very ill infant or child it must be reduced to one half of the standard dosage.

The precordial stethoscope, blood pressure cuff, finger plethysmograph and continuous recording rectal thermometer are used. The small infants are placed on a warm water mattress Thermonator (Fig. 203, p. 433).

For these operations infants and children are anesthetized much like adults. In older children two 18 gauge styletted needles are placed in veins under local or cyclopropane anesthesia. In infants a cut down is placed in the saphenous vein at the ankle. If a nasogastric tube is in place for the treatment of intestinal obstruction, the tube is flushed out with normal saline and allowed to drain freely. In spite of assiduous efforts to empty the stomach, it is surprising how many of these children vomit around the nasogastric tube; this may be prevented by using a larger-bore or cuffed gastric tube. A good sized aspirating catheter is always at hand for pharyngeal aspiration in the event that vomiting occurs during induction of anesthesia. We prefer to anesthetize the patient quickly with cyclopropane, then to give intramuscularly or intravenously 0.5 mg/kg of body weight of succinylcholine chloride to facilitate the intubation.

Following intubation, anesthesia is continued with cyclopropane by absorption in circuit or nonrebreathing technic with manually or mechanically controlled respiration. Surgery is facilitated by succinylcholine chloride intravenously given as a continuous drip or small intermittent doses.

Blood is administered throughout the operation. A falling blood pressure and rising pulse rate, pallor of the face and coolness of the extremities indicate the need for more blood. The face, however, is often pale during the exteriorization of the intestine. If this pallor does not disappear on closure of the abdominal cavity, then more blood usually is required.

A very important prophylactic against shock in infants and children, not so remarkable in adults, is the administration of calcium gluconate accompanying blood transfusion. The dosage is 50 to 100 mg/100 ml of blood administered slowly, and the brighter red color of the blood of the extremities or in the wound often denotes the strengthening of myocardial contraction and improved pulmonary blood flow.

Surgeons sometimes can assist abdominal wound closure or avoid abdominal distention by suctioning trapped air out of the dilated intestine with a hypodermic needle attached to a suction.

Even after several hours of surgery these patients move and cry almost immediately upon extubation. After prolonged surgery, however, these patients are placed in a cold, moist atmosphere to cure any subglottic

care must be provided The patient is changed frequently from side to side Secretions are gently and frequently aspirated out of the mouth and pharynx, and the patient is aroused every hour for a short time to aid in expansion of the lungs Intermittent positive pressure breathing for ten minutes every four hours during the first two days postoperatively helps to expand the right lung. During the first twenty-four hours the infant should have tracheobronchial aspiration, with oxygen by mask between aspirations, and intramuscular injections of 0 5 ml of nikethamide (Coramine) Daily diagnostic x-rays of the chest are taken, since atelectasis, pneumonia, and hemothorax are the commonest causes of death in the first few days postoperatively Daily fluids are restricted to 50 to 100 ml of 5 per cent glucose in water per kg of body weight.

Excision of Esophageal Duplication

Patients with esophageal duplication alone are managed in a manner similar to those with tracheoesophageal fistula. However the patient with esophageal duplication is not handicapped by lung contamination from either the stomach or the proximal blind esophageal pouch.

OPERATIONS ON THE STOMACH AND INTESTINES

Gastroenterostomy; Gastrectomy; Repair of Perforated Gastric Ulcer Gastrostomy; Repair of Perforated Intestine; Excision of Meckel's Diverticulum, Reduction of Intussusception or Volvulus; Colectomy; Removal of Mesenteric Cysts; Removal of Intraperitoneal and Retroperitoneal Tumors; Excision of Duplication of the Intestine; Resection of the Intestine and Colostomy

This group of operations represents the largest number of major surgical operations in the abdomen. Some of them are done infrequently For example, gastroenterostomy is used occasionally in an infant or a child to bypass a duodenal atresia. A repair of a perforated ulcer occurs on rare occasions. Gastrostomy is performed for feeding purposes in such instances as following a tracheoesophageal fistula repair or caustic burns of the esophagus. The remainder of the operations in this group are not unusual pediatric procedures. In a large number of them, the disease itself may have greatly increased the anesthetic risk. Considerable blood loss may have occurred or will occur during surgery Marked abdominal distention may be present. Grave fluid and electrolyte imbalance may exist. Often there is time to correct some of these handicaps before surgery thus reducing the anesthetic risk.

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Following intubation anesthesia is continued with cyclopropane by absorption in circuit or nonrebreathing technic with manually or mechanically controlled respiration Surgery is facilitated by succinylcholine chloride intravenously given as a continuous drip or small intermittent doses

Blood is administered throughout the operation A falling blood pressure and rising pulse rate pallor of the face, and coolness of the extremities indicate the need for more blood The face however, is often pale during the exteriorization of the intestine If this pallor does not disappear on closure of the abdominal cavity, then more blood usually is required

A very important prophylactic against shock in infants and children, not so remarkable in adults is the administration of calcium gluconate accompanying blood transfusion The dosage is 50 to 100 mg/100 ml of blood administered slowly, and the brighter red color of the blood of the extremities or in the wound often denotes the strengthening of myocardial contraction and improved pulmonary blood flow

Surgeons sometimes can assist abdominal wound closure or avoid abdominal distention by suctioning trapped air out of the dilated intestine with a hypodermic needle attached to a suction

Even after several hours of surgery, these patients move and cry almost immediately upon extubation After prolonged surgery however these patients are placed in a cold moist atmosphere to cure any subglottic

edema but if the infant has a low body temperature, then such treatment should not be instituted

In the young infant, especially in the newborn, atelectasis is always a threat Cyanosis of the tips of the extremities, indrawing of the inter costal spaces, paradoxical breathing, the presence of rales and increasing heart rate must be taken as evidence of early atelectasis, for which treat ment is aspiration of the throat, intramuscular injection of nikethamide (Coramine) or caffein sodium benzoate, changing the position of patient from side to side and application of intermittent positive pressure breath ing

Electrolyte and fluid balance following surgery is regulated by the pediatrician Postoperatively, the stomach is kept deflated by a gastric drainage tube Even in these extensive operations, postoperative ileus or death from embolism is an exceedingly rare complication However, in the infant it is not uncommon to see postoperative intestinal obstruction from bands or adhesions

Pyloromyotomy

Infants with pyloric stenosis have protracted vomiting with a consequent loss of water and electrolytes There is a much greater loss of chloride than of sodium, causing a metabolic alkalosis To compensate for the chloride loss there is a compensatory retention of bicarbonate ion caused by depression of respiration and by renal tubular reabsorption of the bi carbonate If an infant with pyloric stenosis has a respiratory rate around 30/minute or slower it strongly suggests uncorrected metabolic alkalosis In addition a significant amount of potassium ion is lost in the vomitus and in the urine This hypokalemia causes muscle weakness and fish mouth breathing

Loss of weight and lack of tissue turgor indicate the degree of dehydra tion Hemoglobin and plasma protein values indicate the degree of de-hydration anemia and hypoproteinemia Plasma carbon dioxide and chloride levels reflect the degree of alkalosis and afford a guide for re-placement therapy with an alkaline urinary pH further emphasizing the degree of alkalosis

Since it is recognized that pyloric stenosis is not a surgical emergency 48 to 72 hours may be allowed for the preparation of the patient Fluid and electrolyte balance is achieved with Ringer s or hypotonic Ringer s solution, the latter providing sodium, potassium calcium and chloride

Usually 150 to 200 ml/kg of body weight of this hypotonic Ringer's solution are given to the infant over a 24-hour period, and this is continued until his dehydration is cured and his electrolytes approximate normal Extra potassium is provided in moderate to severe alkalosis, by potassium chloride, 2 to 3 mEq/kg of body weight, diluted in the total daily fluid needs After one to three days of initial hydration and salt replacement Amigen may be given The anemia and hypoproteinemia are corrected by a small blood transfusion 25 ml/kg of body weight The optimum time for the pyloromyotomy is when the fluid and electrolyte balance is close to normal

A No 12 French nasogastric tube is inserted in the infant on the ward, lavaged with saline until clear, and left in place when he is sent to the operating room

For preanesthetic medication, these infants, usually about three to six weeks of age, are given atropine, 0 1 mg (gr 1 600) to 0 06 mg (gr 1 1000), intramuscularly one half hour prior to surgery

Infants with pyloric stenosis, possibly because of their recent lack of protein intake, have a marked tendency to lowered body temperatures when exposed to a cool atmosphere The infant is brought to the operating room in a warm incubator Conservation of body heat during operation is accomplished by warming the operating room to 23 9° C (75° F) and placing the patient on a rubber mattress or hot water bottles containing water heated to 40° C (104° F) The rectal temperature is recorded continuously

Just prior to induction of anesthesia, all fluid and air are aspirated from the stomach (Fig 173), if the gastric tube has become blocked with gastric secretions, it is removed and replaced with a new one In addition to the precordial stethoscope an electrocardiograph, a carbon dioxide analyzer, or a finger plethysmograph may be used to monitor the heart

Anesthesia is induced with cyclopropane, followed by succinylcholine chloride intravenously or intramuscularly in 2 to 4 mg doses As soon as the patient is relaxed, a No 14 French oral endotracheal tube is inserted

Anesthesia is continued with a mixture of cyclopropane and oxygen by the infant circle absorption technic (Fig 174) or nonrebreathing valvular technic (Fig 175) using controlled respiration to overcome resistance in the equipment However, hyperventilation with consequent respiratory alkalosis is avoided, for this would exaggerate the residual metabolic

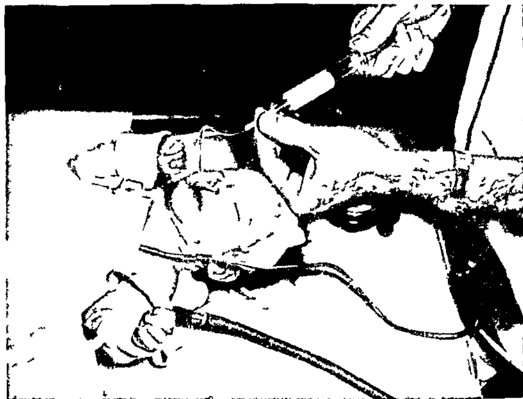


Fig 173 Through the nasogastric tube the patient's stomach is aspirated before anesthesia

alkalosis and might produce tetany Abdominal relaxation is obtained if necessary, with the use of succinylcholine chloride in 2 to 4 mg doses If secretions are heard in the small endotracheal tube it should be cleaned out with a fine polyethylene suction catheter

Other methods of anesthesia include infant circle filter with a mask using cyclopropane or open drop ether with oxygen flowing under the mask (Fig 176) Ether tends to produce a metabolic acidosis and improve the breathing, although induction of anesthesia may be prolonged by alkalotic suppressed respiration and a tendency to breath holding If the infant is premature or emaciated the operation may be performed under local anesthesia

Little is necessary in the form of electrolyte solutions or blood during surgery Occasionally unforeseen bleeding at the operative site may necessitate the use of a small blood transfusion through a cut down

As soon as the operation is over, the infant is placed in a warm incubator to prevent an alarming postoperative apnea from hypothermia When the patient has fully reacted the nasogastric tube is removed, and the



Fig 174 Patient anesthetized preparatory to the correction of a pyloric stenosis An infant Heidbrink circle filter is being used with cyclopropane as the anesthetic agent

patient is returned to the ward Approximately six hours after surgery, the postpyloric feeding schedule is instituted

Operation for Meconium Ileus

Meconium ileus is the accumulation of inspissated meconium in the terminal ileum causing intestinal obstruction with severe distention of the small bowel The inspissated meconium is said to be due to a lack of excretion of trypsin from the pancreas This is a disease of the newborn and if the infant survives the first few weeks of life he later may show fibrocystic disease of the lung

The surgical treatment is either an abdominal laparotomy, opening up the terminal ileum and attempting to clean out the puttylike meconium or resecting the terminal ileum doing a colostomy and for the next two or three weeks cleansing the remainder of the ileum and colon through the colostomy Two to three weeks later the bowel is anastomosed Sometimes the surgeon uses a variety of substances to help liquefy this puttylike meconium The pharmacological effects of such substances should be

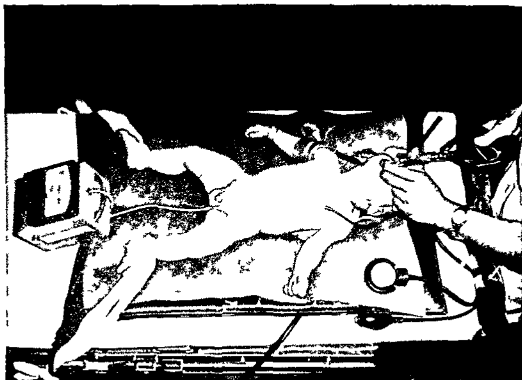


Fig 175 For correction of this pyloric stenosis the nonrebreathing technic and cyclopropane are used The anesthesiologist s finger on the hard palate extends the head of the patient and minimizes the likelihood of kinking of the endotracheal tube The warm water mattress is maintained at body temperature and the rectal tempera ture is being monitored continuously

familiar to the anesthesiologist for it is conceivable that toxic amounts can be absorbed by the patient

The anesthetic management is the same as that previously outlined for operations on the stomach and intestines (p 362)

If subsequent operations are necessary fibrocystic disease of the lungs may have made its appearance Special care must be taken with the pa tient if this complication is present The largest possible endotracheal tube should be employed in order to avoid obstruction to exhalation, the gases should be humidified, and overdistention and rupture of the lungs avoided

Postoperatively, these infants are subject to atelectasis and consequently are kept in a cool moist atmosphere Nikethamide (Coramine) 0 5 to 1 0 ml intramuscularly every hour postanesthetically until there is no atelectasis present is valuable treatment

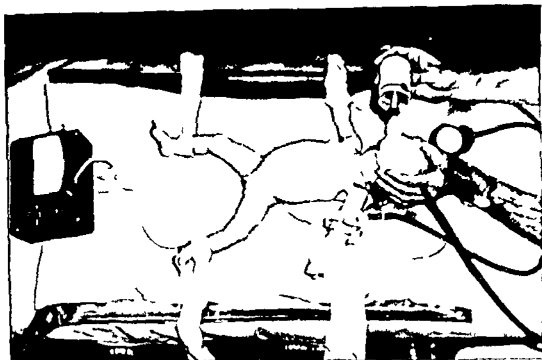


Fig 176 Open drop ether technic for pyloromyotomy A source of oxygen is delivered beneath the mask The child is lying on a warm water mattress and the rectal temperature is monitored continuously

OPERATIONS ON THE APPENDIX

Appendectomy

Acute appendicitis is most frequently seen in children over four years of age but can occur in infants The disease tends to cause a metabolic acidosis and dehydration because of inadequate food and fluid intake These are the direct results of the anorexia and emesis If the urine contains acetone and diacetic acid, the patient is given intravenously 5 per cent glucose in water before anesthesia Since an appendectomy is an emergency operation, often there is inadequate time to correct the acidosis Most of these patients may be given full sedative premedication, for often there is a hyperpnea from the metabolic acidosis

There are several methods of anesthesia suitable for this operation One is cyclopropane induction with the circle filter and mask, and then intravenous injection of succinylcholine chloride, or even d tubocurarine in older children to facilitate intubation Intubation is selected since it reduces the dead space, provides a ready means of ventilating the lungs, and keeps the respiratory acidosis at a minimum, it being inadvisable to en-

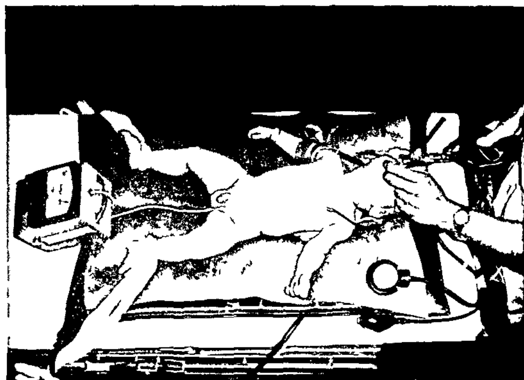


Fig 175 For correction of this pyloric stenosis the nonrebreathing technic and cyclopropane are used The anesthesiologist s finger on the hard palate extends the head of the patient and minimizes the likelihood of kinking of the endotracheal tube The warm water mattress is maintained at body temperature and the rectal temperature is being monitored continuously

familiar to the anesthesiologist for it is conceivable that toxic amounts can be absorbed by the patient

The anesthetic management is the same as that previously outlined for operations on the stomach and intestines (p 362)

If subsequent operations are necessary, fibrocystic disease of the lungs may have made its appearance Special care must be taken with the patient if this complication is present The largest possible endotracheal tube should be employed in order to avoid obstruction to exhalation, the gases should be humidified, and overdistention and rupture of the lungs avoided

Postoperatively, these infants are subject to atelectasis and consequently are kept in a cool, moist atmosphere Nikethamide (Coramine), 0 5 to 1 0 ml intramuscularly every hour postanesthetically until there is no atelectasis present is valuable treatment

Although one hour may be required for preparation, the advantages of mild hypothermia in these cases are dramatic, these are reduction in the febrile response to infection, creation of a state of physiological rest, and provision of an elective anesthesia with a consequent greater margin of safety for the patient In addition, the danger of generalized convulsions is minimized at this reduced body temperature

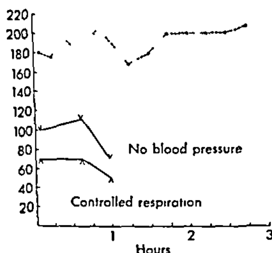


Fig 177 A chart of a very ill patient undergoing removal of a ruptured appendix without hypothermia The top dotted line indicates the course of the pulse rate About three minutes after the commencement of the anesthesia the blood pressure took a precipitous drop The patient remained in deep shock until his demise the first day postoperatively

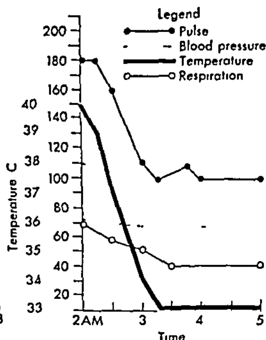


Fig 178 A chart of a patient with acute appendicitis and secondary peritonitis After the patient was anesthetized with cyclopropane he was operated upon under moderate hypothermia dropping the temperature from 40 to 33 C The pulse during this time dropped from 180 to 100 The appendix was removed and the patient made an uneventful recovery

On account of the distention of the abdomen and some increased abdominal muscle tone due to the hypothermia it may be necessary to give very small doses of succinylcholine chloride The minimal dose should be given intravenously and the length of time of muscle relaxation noted so that the next dose of succinylcholine chloride may be determined

Because of the kidney suppression and the peritonitis, the anesthesiologist should be extremely cautious in his use of any muscle relaxant, which might produce a prolonged apnea, in fact, the dosage of all anesthetic agents should be kept to a bare minimum, and hypothermia facilitates this If hypothermia is not used even if the anesthetic agents are

graft respiratory acidosis on metabolic acidosis Ether is avoided since it increases the metabolic acidosis

The second method is somewhat similar except that the basis of anesthesia is intravenous thiobarbiturate and nitrous oxide inhalation anesthesia muscle relaxation being provided by d-tubocurarine or succinyl choline chloride

The third method which is adaptable to children of seven years and older is spinal anesthesia Since children usually struggle during the introduction of the spinal needle, it is best to anesthetize them lightly for insertion of the spinal anesthetic Cyclopropane anesthesia may be used for this purpose Light general anesthesia is also used throughout the procedure to prevent agitation, nausea, and emesis The blood pressure should be followed closely during induction and maintenance of anesthesia The profound muscle relaxation and the ribbonlike bowel produced by the spinal anesthesia, together with the lack of metabolic upset are advantages to both the patient and the surgeon

The temperature of these patients is monitored throughout the procedure, for hyperthermia may be a complication and can be corrected with a cooling mattress and with reduced operating room temperature

On occasion the anesthesiologist is confronted with a child with a ruptured appendix of hours or days duration and prolonged intestinal obstruction Accompanying this condition will be lethargy, dehydration hyperpyrexia ketosis tachypnea, tachycardia and a distended and firm abdomen The kidney function is usually suppressed and urine is dark, concentrated, often has albumen, acetone and diacetic acid present These extremely acidotic patients may be in shock with the blood manifesting an elevated hematocrit and hemoglobin, and a high red blood cell count indicative of dehydration

In these extremely ill infants and children the preoperative preparation includes the intravenous administration of 5 per cent glucose in water to stimulate the secretions of urine and to ameliorate dehydration and acidosis Potassium solutions are used cautiously if there is marked suppression of urine The body temperature is reduced and the pulse rate lowered before surgery with alcohol sponges, ice bags and scanty covering Atropine alone is given for premedication

These patients may be anesthetized with inhalation anesthesia our choice being cyclopropane They are intubated with the aid of a minimum amount of relaxant drug The body temperature is then lowered, by resting the patient on ice bags or a cooling mattress, usually resulting in a very rapid heart rate falling to 120 or 100 per minute (Figs 177 and 178)

Fig 180 A patient positioned for proctoplasty Endotracheal technic is used and the anesthesiologist ventilates the lungs either manually or mechanically

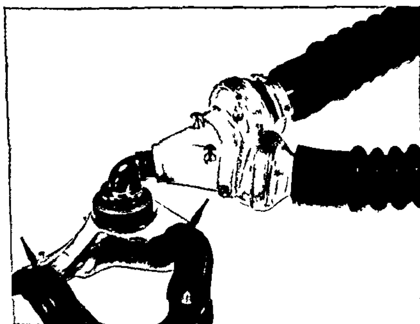


Fig 181 A close up enlarged view of the Digby Leigh circle filter valve One domelike housing contains an inhalation valve while the other contains an exhalation valve The shape of this housing reduces tremendously the turbulence to airflow

kept at minimal dosages, the patient may develop an apnea and never recover from it

We have noted that when these very ill children have a temperature reduction and a slower heartbeat, they usually survive the surgery and anesthesia and have a very good prognosis postoperatively if hyperpyrexia is avoided in the postoperative period

OPERATIONS ON THE RECTUM AND ANUS

Proctoscopy, Proctoplasty, Closure of Rectovesical, Rectourethral, and Rectovaginal Fistula, Anoplasty, Dilatation of Anal Sphincter, Combined Abdominal Perineal Repair

The anesthetic management for the operations in this group is similar to that outlined for operations on the stomach and intestines except that relaxation of the abdominal muscles is not usually required (Figs 179, 180, 181) However, in abdominal perineal repair, abdominal muscle



Fig 179 An infant about to undergo a proctoscopy has been anesthetized with cyclopropane-nitrous oxide anesthesia using nonrebreathing valvular technic

In patients with lacerations of the liver, blood loss is generally excessive, and provision must be made for replacement of blood before and even after surgery Anesthetic management is similar to that for operations on the stomach and intestines (See p 362)

Removal of Liver Tumor or Cyst

The anesthesia for these operations is managed like that for operations on the stomach and intestines, although considerable blood loss should be anticipated and must be replaced (See p 362)

OPERATIONS ON THE BILIARY TRACT

Biliary Tract Exploration and Possible Choleduodenostomy (Biliary Atresia)

Infants with biliary atresia are cachectic jaundiced and somewhat lethargic but live a surprisingly long time in spite of intense jaundice and disturbance of liver function Their cardiac reserve is often reduced by the chronic illness Such patients are prepared the same as patients for any operation on the stomach or intestines (see p 362) Premedication is scopolamine alone

A nonexplosive technic is used, since it is common practice to inject radiopaque dye into the gallbladder and trace the outline of the biliary tract system by x-ray

A minimum of anesthetic agents such as a combination of nitrous oxide with small intermittent doses of succinylcholine chloride, is used Endotracheal with nonrebreathing or infant absorption in circuit technic is employed Even minimal doses of thiobarbiturate can be used in spite of the liver damage Surgical correction of many of the biliary atresias is impossible, and even though the patient recovers from anesthesia and surgery, his ultimate prognosis is usually grave

OPERATIONS ON THE ABDOMEN, PERITONEUM, AND OMENTUM

Exploratory Laparotomy, Drainage of Peritoneal Abscess (Subdiaphragmatic), Division of Peritoneal Adhesions, and Resuture of Abdominal Wall

Management of anesthesia for the above surgical procedures is similar to that described for operations on the stomach and intestines (p 362)

relaxation is a necessity, also generous blood replacement through intra venous needles in the forearm or hand is essential Unlike adults, infants, when changed from the lithotomy to the supine position at the end of the operation, seldom demonstrate hypotension

Postoperative observation and treatment following combined abdominal perineal repair are particularly concerned with early detection of inadequate replacement of blood during surgery or a continuing loss postoperatively

OPERATIONS ON THE LIVER

Drainage of Liver Abscess

Infants or children with a liver abscess often present a difficult diagnostic problem, and the delay in diagnosis may bring about marked emaciation due to infection, hyperpyrexia, and prolonged inactivity Emotional dis turbances are common, and therefore sedative premedication is indicated The prolonged illness may considerably reduce the patient s myocardial reserve

Usually the patient is anesthetized with inhalation anesthesia, using a minimum of anesthetic agents, since analgesia alone is required The surgeon attempts to locate the abscess by exploration with a needle If pus is located, an incision is made to drain the abscess

Biopsy of Liver

The preparation of the infant or child for biopsy of the liver must in clude a critical evaluation of the patient s particular disease Premedica tion and management of the anesthesia are similar to that for operations on the stomach and intestines Although theoretically thiobarbiturates should have a prolonged effect in such a patient in our experience this has not appeared clinically factual Since continued oozing of blood from the liver bed after the biopsy occasionally occurs, cross matched blood should be available Careful observation of the patient for several hours after operation will detect any delayed oozing

Hepatorrhaphy (Suture of Liver Laceration)

Because of the numerous accidents which occur in the infant and child age groups a lacerated liver is frequently seen by the pediatric anesthesi ologist These lacerations vary in their severity In one instance that comes to mind the entire left lobe of the liver was severed from the right lobe

bradycardia, or irregularity of the heart on the electrocardiogram Consequent postoperative pulmonary insufficiency may also occur as a result of restriction of the descent of the diaphragm Because of this, the surgeon may not attempt to close the muscle layers of the abdominal wall but may be content with a skin closure with suturing of the fascial and muscle layers a few months later Nikethamide (Coramine), 0 5 to 1 0 ml, intramuscularly every hour until the infant's color remains pink and he can emit a vigorous cry, and intermittent positive pressure breathing both elevate the survival rate



Fig 182 An infant undergoing a left inguinal herniorraphy under light cyclopropane anesthesia with endotracheal and infant circle absorption technic The anesthesiologist is controlling the respiration

Repair of Congenital Diaphragmatic Hernia

Congential herniation of abdominal organs through the left leaf of the diaphragm prevents expansion of the left lung and displaces the mediastinum to the right, while the opposite lung develops a compensatory hyperdistention of its alveoli

The condition is usually diagnosed in the newborn from the intermittent bouts of cyanosis and the chest roentgenogram showing loops of bowel occupying the left chest and marked displacement of the heart to the right

Hernioplasty Inguinal, Femoral, Umbilical, Ventral, and Epigastric

These operations are performed on infants and children of all ages Inguinal hernia is extremely common and is repaired as soon as discovered in order to prevent strangulation and incarceration

Preanesthetic medication in infants is ordinarily scopolamine or atropine Older children receive a barbiturate and an opiate or opiate like drug in addition to the drying agent A precordial stethoscope and blood pressure cuff are applied Atropine premedication only and a light stage of anesthesia produced by open drop ether with its spontaneous vigorous respiration are certainly the method of choice for the inexperienced pediatric anesthesiologist A moderately rapid recovery results from this technic Lately, however, there has been a tendency, as in adults to use cyclopropane anesthesia in these patients, employing infant circle filter with mask and assisted ventilation throughout One of the dangers with this technic is that insufficient depth of cyclopropane anesthesia may predispose the patient to sudden, severe, alarmingly sustained laryngospasm, therefore, succinylcholine chloride should be ready for intravenous or intramuscular injection at the onset of laryngospasm With the subsequent muscle relaxation produced by succinylcholine chloride, intubation can be accomplished readily Preferably, cyclopropane should be administered and an elective intubation performed before the commencement of the surgery (Fig 182) With this technic, the infant or child is awake as soon as the dressing has been applied Also, nausea and emesis are minimal with this technic

Repair of Omphalocele

The congenital anomaly, omphalocele, requires an emergency operation, since rupture of the thin sac covering the intestines causes peritonitis, a fatal condition to the newborn infant

No premedication is required, and the management of anesthesia is similar to that for operations on the stomach and intestines (Fig 183) (See also Chapter 27 p 423, with reference to anesthesia in the premature and newborn infant) However the most vital part of the management of the anesthesia is the time of attempted replacement of the viscera into the abdominal cavity, since the shallow abdominal cavity has not enlarged to accommodate all these organs Attempted closure of the anterior abdominal wall over the intestines may result in serious embarrassment to respiration and circulation, as evidenced by marked tachycardia,

Preanesthetic medication in the newborn may be omitted, since tracheobronchial secretions are inconsequential the first week of life Provision is made for the administration of blood through a cut down in the saphenous vein at the ankle in the infant or by two styletted needles in the child

Cyclopropane anesthesia and oral endotracheal technic with an infant circle absorption or nonrebreathing valvular technic are used The anesthetic risk is compounded by this transthoracic operation in a partially asphyxiated neonate

As much as possible, the infants are allowed to breathe on their own, if assisted or controlled ventilation is necessary, extreme care is exercised in the amount of pressure used in order to prevent any further overdistention of the hyperdistended alveoli Excessive pressure directed at the collapsed left lung is unwise, since rupture of already expanded alveoli and pneumothorax may occur in the contralateral lung

Both circulatory and further respiratory embarrassment are likely to occur when the abdominal viscera are replaced in the small abdominal cavity An electrocardiogram may show bradycardia tachycardia, elevated S T segment, or enlarged T wave These abnormal signs probably arise, first, from limitation of the descent of the diaphragm, and, second, from elevation of the venous pressure which occurs by compressing the splanchnic veins Increased respiratory insult is also due to diaphragmatic restriction causing limitation of motion of the right lung This pulmonary insufficiency is corrected only with full expansion of the left lung, several hours or days after the operation Of course, as the abdomen stretches with its new contents, the action of the diaphragm is more freely accomplished

Postoperative fatalities are not uncommon and usually are due to some respiratory complication such as atelectasis emphysema with pneumothorax, or a progressive chronic hyperpyrexia of some hours, or days', duration Postoperatively, therefore, these patients require constant vigilance and treatment similar to that previously described for repair of omphalocele

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Fig 183 A two-day-old infant ready for an omphalocele repair He is on a warm water mattress his temperature is monitored with a rectal thermometer There is a cut-down in the left saphenous vein through which blood can be introduced

with compression atelectasis of adjacent lung fields The demonstration of barium in the herniated bowel completes the diagnosis

Surgical treatment consists of replacing the intestine and other herniated abdominal viscera in the abdominal cavity and closing the aperture in the diaphragm through an abdominal or thoracoabdominal incision A closed water seal may be attached to the pleural cavity to aid the expansion of the collapsed left lung Before the hernioplasty an emergency thoracotomy to relieve the intrapleural pressure may be necessary in the severely distressed infant

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The preanesthetic sedation will be decreased for the underweight, anemic, ill patient with severe renal impairment

Certain measures should be followed in the anesthetic management of the ill patient with impaired renal function use of endotracheal technic to provide an airway for adequate pulmonary ventilation of both lungs, particularly the dependent lung often compressed by the kidney bar (Fig 184), use of gaseous anesthetic agents readily eliminated by the lungs,

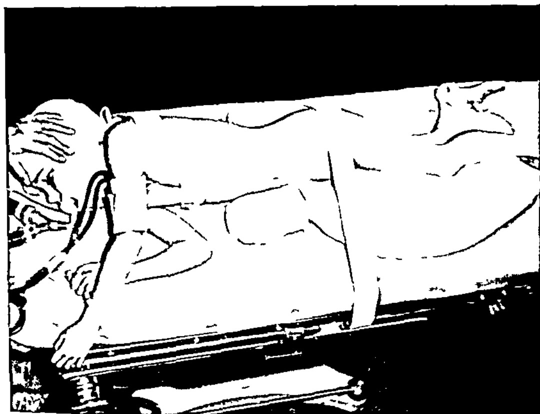


Fig 184 A child in a lateral position for nephrostomy or nephrectomy There is a sand pillow acting as a kidney bar Ventilation of the lungs during this procedure is essential to avoid compression atelectasis in the dependent lung

limitation of fluids to minimize pulmonary edema, adequate blood replacement for an anemic patient with low cardiac reserve

On completion of surgery the patient should be turned from the lateral to the supine position and the chest examined for signs of compression atelectasis on the formerly dependent side

In the recovery room, hypertension and pulmonary edema are two of the more severe sequelae of the procedure Positive pressure breathing may be helpful for the treatment of pulmonary edema

CHAPTER 23

OPERATIONS ON THE UROGENITAL SYSTEM

THE URINARY SYSTEM

OPERATIONS ON THE KIDNEY OR KIDNEY PELVIS

Drainage of Kidney or Perirenal Tissues (Nephrostomy)

Nephrostomy is usually done to drain a hydronephrosis, a result of urinary tract obstruction which has caused backward pressure If the obstruction is low down in the urinary tract the bladder and ureters also may be dilated The anesthesiologist should discuss with the pediatric urologist the disorders of micturition and renal function In the older child disorders of micturition may give rise to psychological problems, whereas chronic disorders of renal function may produce an anemic, sallow, and underweight child

The urinalysis hemogram, renal function tests blood chemistry—particularly the blood urea—provide evidence of the degree of renal impairment The diagnosis which indicated the need for nephrostomy usually has been confirmed by the intravenous or intramuscular pyelogram, the cystoscopy, or the retrograde pyelogram The performance of cystoscopy and retrograde pyelogram requires general anesthesia

The anesthesiologist will also discuss with the urologist his proposed operation, positioning of the patient, which will likely be the lateral position with elevated kidney bar probable blood loss, use of electrocautery, degree of relaxation required and fluid and electrolyte balance, especially if there has been emesis and impaired renal function

OPERATIONS ON THE URETER

Removal of Calculus, Ureteroplasty, or Transplant of Ureters

Ureteral plastic operations are sometimes performed on long, tortuous, dilated ureters Such ureters are straightened, shortened, and the lower end anastomosed to the bladder or large intestine

Anesthesia is similar to that administered for nephrectomy, except that more muscle relaxation is provided by minimal amounts of succinylcholine chloride so that the work of the surgeon may be facilitated

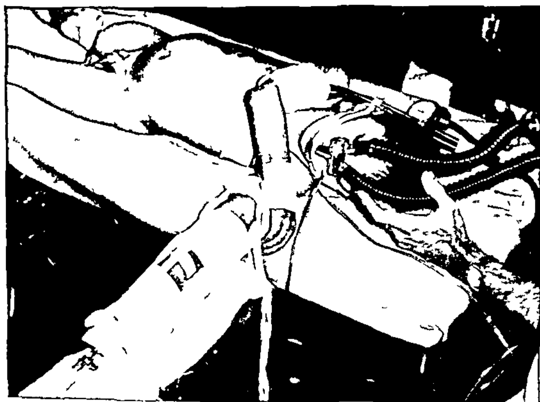


Fig 185 A child positioned in the semilateral position for removal of a large Wilms tumor Anesthesia is the endotracheal circle absorption technic A nasogastric tube is in place a cut-down in the left arm is attached to the infusion tubing by a three way stopcock

OPERATIONS ON THE BLADDER

Cystotomy

Suprapubic cystotomy, performed for correction of vesical rupture or retention, is done with the patient in the supine position Seldom is there marked kidney impairment

Nephrectomy

Removal of the kidney in children is usually necessary for one of three conditions embryoma (Wilms' tumor), ruptured kidney, or hypoplastic kidney Of these, the most commonly occurring condition is embryoma, a rapidly growing tumor not noticeable at birth, but usually appearing prior to the fifth year of age

In his preanesthetic evaluation of the patient the anesthesiologist must consider dehydration, malnutrition, anorexia, and especially the rapidity of growth of any tumor present Hypertension is often a concomitant finding in patients with hypoplastic kidneys Patients with embryoma or ruptured kidney frequently demonstrate hematuria often enough to necessitate blood replacement For this reason blood for transfusion is always ready, and a cut-down is performed in the lower leg or arm in small infants or two 18 gauge styletted intravenous needles are inserted in older children These precautions are significant in any renal operation because there is always the possibility that not only hemorrhage may occur from one of the renal vessels, but also the dissection of a large renal tumor may be traumatic, bloody, and prolonged

If there is no profound kidney dysfunction patients scheduled for nephrectomy are given the usual premedication in accordance with their age and weight

Before anesthesia, the anesthesiologist should check with the chart and with the surgeon to find out on which side the nephrectomy is to be performed These patients are given nitrous oxide supplemented with either cyclopropane, trichlorethylene, or Fluothane Succinylcholine chloride is *given to facilitate intubation The urologist postures the patient* Very little muscle relaxation is required since the operation is retroperitoneal However for removal of a large Wilms' tumor the patient is placed in the supine position In this instance abdominal muscle relaxation and blood replacement are essential (Fig 185) If the patient has been in the lateral position the anesthesiologist should lower the kidney bar when he observes that this procedure will facilitate wound closure

At the end of the operation, the patient is turned on his back, and both sides of the chest are carefully watched and auscultated Cyanosis or diminution of expansion or of breath sounds in the formerly dependent chest should make the anesthesiologist suspicious of atelectasis Atelectasis, however, is exceedingly rare during nephrectomy in children as compared to its frequency observed in the adult patient

sedation should be reduced In preparing for a resection of the bladder neck, the anesthesiologist anticipates a severe blood loss during surgery

Endotracheal technic and nonexplosive, nonflammable anesthetic agents are employed Blood replacement during surgery is an important function of the anesthesiologist

Postoperative care is similar to that following nephrostomy or nephrectomy, but close observation of color, blood pressure, and pulse must be kept to detect the presence of bleeding



Fig 187 For a cystoscopy a child receiving nitrous oxide and Fluothane anesthesia using a mask and circle filter

Cystoscopy and Retrograde Pyelogram

Many of the patients who undergo cystoscopy and retrograde pyelogram are very ill and require a critical preanesthetic assessment Severe impaired renal function or massive pleural effusion must not be overlooked

Premedication will vary with the preanesthetic evaluation of the patient Infants or children with no impairment of kidney function will receive the standard doses of premedication

A nonexplosive nonflammable technic such as nitrous oxide and trichlorethylene or nitrous oxide and muscle relaxants is required because of the x-ray filming (Fig 187) Endotracheal anesthesia avoids respira-

Our standard premedication is given Since blood loss in the ordinary case is not excessive, replacement is not necessary

Although endotracheal intubation is not mandatory, we prefer to take advantage of its many attributes (Fig 186) Generally, cyclopropane anesthesia and the circle absorption technic are used even though there is a variety of suitable agents and technics for cystotomy



Fig 186 A cystotomy being done with nitrous oxide and trichlorethylene anesthesia with a nonrebreathing valve attached to the endotracheal tube

Resection of Bladder Neck

One of the causes of obstruction to the urinary system in infants is congenital constriction of the bladder neck Such a patient may have a resultant hydronephrosis or pyelonephritis from the obstruction which is relieved by operative resection of the bladder neck Preanesthetic evaluation of this patient depends upon the urinalysis, the blood analysis and the effectiveness of antibiotics in controlling the stasis induced pyelonephritis

With little manifestation of kidney dysfunction, the patient can be given the standard premedication but with diminished kidney function

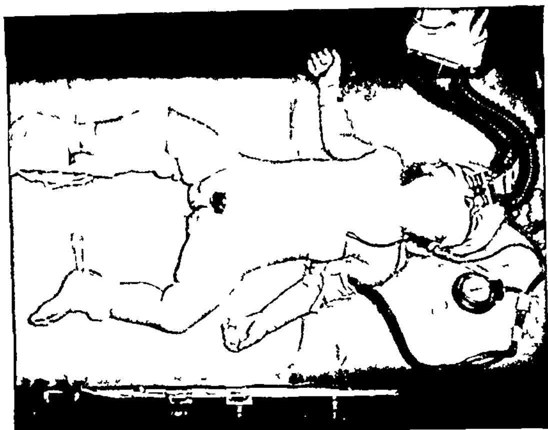


Fig 188 For repair of extrophy of the bladder the patient is receiving cyclopropane anesthesia There is a cut-down in the saphenous vein of the right ankle so that blood may be transfused as it is lost

THE GENITAL SYSTEM

MALE Circumcision, Plastic Repair to Penis (Hypospadius and Epispadius), Orchidoplasty (Cryptorchidism), Reduction of Torsion of the Testes (Spermatic Cord)

FEMALE Clitoridectomy, Biopsy of Gonads for Sex Determination and Oophorectomy, Closure of Rectovaginal Fistula, Plastic Repair for Double Vagina

The above group of operations encompasses a variety of procedures requiring light anesthesia Our standard preanesthetic medication is given to these patients

For circumcisions cyclopropane, although it may increase bleeding and may cause priapism, is often used instead of ether because of the rapid and comfortable induction which it produces At present, there is a growing tendency to use nitrous oxide and Fluothane for circumcisions because of the reduced bleeding which results with these anesthetic agents

tory acidosis Personnel who are assigned to the x-ray room are protected with lead aprons An intravenous needle is inserted for the administration of fluids or dyes For cystoscopy in the female patient only very light anesthesia is required, since the procedure is less painful in the female than in the male

Cystoplasty (Extrophy of the Bladder)

In recent years a combined team of urogenital and general surgeons have attempted to construct a bladder from the colon the colon being sutured to the suprapubic region and the ureters transplanted into this new bladder In the preanesthetic evaluation, the age of the child is important, most of these operations being done in early childhood There may be other anomalies present which affect the general condition of the patient Many of these patients, kept in bed for some time, lack the vigor of the active child, are malnourished or may have some chronic infection of their exposed bladder All of these factors combine to give them a diminished cardiac reserve and a reduced ability to recover rapidly from the surgical procedure, which is often prolonged and extensive However, since this congenital anomaly is one of the most unfortunate that can occur, any effort to improve the condition of these miserable patients and permit them to live a useful life is well worthwhile

Premedication in these children depends again on their general condition If they are handicapped, underweight, and have been bedridden, premedication should be reduced Anesthetic management is the same as for operations on the stomach and intestines, using as little anesthetic agent as possible The anesthesiologist must endeavor to keep pace with the blood loss by blood replacement (Fig 188) Because of the large amount of blood often needed to replace the constant oozing calcium gluconate should be given intravenously slowly, 50 to 100 mg after every 100 ml of blood

Following extubation at the end of surgery, patients often appear somewhat pale and in mild shock, although the blood pressure and pulse are usually normal This condition is probably due to prolonged surgery and anesthesia in a debilitated patient, and often requires no treatment if sufficient blood has been given It is advisable however to put these patients in cold, moist atmosphere to prevent subglottic edema which might occur following four to five hours of intubation

CHAPTER 24

OPERATIONS ON THE ENDOCRINE SYSTEM

From our very limited experience in anesthesia for operations on the endocrine system, in this chapter we offer some of the theoretical and practical points which concern the pediatric anesthesiologist

ADRENALECTOMY FOR ADRENAL CORTICAL HYPERFUNCTION

Hyperadrenalism, otherwise known as Cushing s syndrome, is a symptom complex of excess adrenal cortical activity Hyperadrenalism is sometimes caused by a malignant tumor or benign hyperplasia of the adrenal glands One of the more radical attempts at cure of this condition is total bilateral adrenalectomy Hyperaldosteronism, a form of adrenal hyperfunction in which patients demonstrate hypertension, weakness and hypokalemia, may be caused by benign or malignant tumors or hyperplasia of the adrenal cortex Surgical removal is again an attempted method of cure

Usually children scheduled for adrenalectomy because of adrenal cortical hyperfunction are preoperatively prepared with hydrocortisone The electrolyte and hormone therapy is administered according to the advice of the pediatrician or endocrinologist For these patients, the anesthesiologist should have ready hydrocortisone and in addition, norepinephrine in a concentration of 1 mg in 500 ml of normal saline

For preanesthetic medication, moderate doses of a barbiturate, an opiate, and scopolamine are suitable Anesthesia for excision of an adrenal tumor is similar to that for operations on the stomach and intestines, using cyclopropane, a muscle relaxant, and endotracheal technic

For the longer, more hemorrhagic hypospadius operations where cautery necessitates a nonexplosive technic, a combination of intravenous thio barbiturate, and nitrous oxide and trichlorethylene with nonrebreathing technic, or nitrous oxide and Fluothane with absorption technic may be employed Other nonexplosive methods such as nitrous oxide and intra venous or intramuscular succinylcholine chloride, with or without minimal amounts of meperidine (Demerol) and thiobarbiturate may also be used

Biopsy of gonads for sex determination is performed early in life so that a male or female pattern of life can be determined early The usual premedication and anesthetic methods used for surgery on the stomach and intestines are employed (See p 362)

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These patients are monitored continuously with an electronic thermometer and kept cool by lowering the temperature of the operating room, while any elevation of body temperature is reversed quickly by placing the patient on ice bags The heart also is monitored by an electrocardiograph and any marked tachycardia is reduced by further lowering of the body temperature Extubation follows the application of the dressing The anesthesiologist then examines the vocal cords to determine whether there is adduction paralysis of them from injury to the recurrent laryngeal nerve

Postoperatively, the patient is observed closely for respiratory obstruction from a paralyzed vocal cord or a hemorrhage which compresses the trachea Sterile scissors and forceps should be available to cut the dressings and the sutures to release accumulating blood An endotracheal tube, laryngoscope, and tracheostomy tube also should be at the bedside to relieve any severe respiratory obstruction Some of these patients because of the manipulation of the thyroid gland, do show increased metabolism postoperatively and become restless from this relative hypoxia, they should be given oxygen therapy These children are immediately placed in a cold, moist atmosphere to reduce to a minimum any traumatic subglottic edema from the endotracheal tube, and, at the same time, such treatment lowers their metabolism Postoperatively, large dosages of sedatives may be dangerous, for these patients can rapidly develop an unnoticed respiratory obstruction If exophthalmos is severe, the eyes must be protected during recovery by moistening them with a bland 5 per cent boric acid ointment and by covering them with a shield

The operative removal of carcinoma of the thyroid is similar to any thyroidectomy except that there is total removal of the involved gland Management of the anesthesia and the postanesthetic course is similar to that for removal of a hyperthyroid gland but hypothyroidism is more likely to develop, with low blood pressure, slow pulse, and a drop in body temperature Such a sequela requires treatment by an endocrinologist

EXCISION OF THYROGLOSSAL CYST

Thyroglossal cyst is a common lesion in children The treatment is complete excision of the cyst and sinus

Premedication consists of an opiate barbiturate, and scopolamine The patient is anesthetized with intravenous thiobarbiturate, cyclopropane and then intubated Anesthesia is maintained with nitrous oxide or cyclopropane (Fig 189) The normal postoperative precautions are taken with particular emphasis on vigilance for detection of respiratory obstruction

A drop in blood pressure is reported to occur often on removal of the cortical tumor, although in our experience these patients have not shown any hypotension, but rather a tendency to hypertension, probably from handling of the gland with release of norepinephrine and epinephrine If the blood pressure rises while the child is receiving cyclopropane the anesthesiologist may add either ether or intravenous thiobarbiturate Post operatively, these children are given normal saline and hydrocortisone

ADRENALECTOMY FOR PHEOCHROMOCYTOMA

Hyperfunction of the adrenal medulla from a benign or malignant tumor occurs rarely in children These tumors are designated, as a rule, as pheochromocytoma and are characterized by a hypertension and hyper metabolism which responds to phentolamine (Regitine) The plasma and urine usually contain high levels of epinephrine and norepinephrine, and, since the treatment is surgical removal of the tumor, in preparing for anes thesia the anesthesiologist should have norepinephrine available

In the removal of a pheochromocytoma anesthetic gases must be metered carefully Ether and barbiturates may be advantageous in the early part of the surgery when the gland is being manipulated their use possibly preventing a marked rise in blood pressure and cardiac arrhythmias Later however if the blood pressure commences to fall after the removal of the tumor, ether should be discontinued and cyclopropane used Should the blood pressure still continue to fall, then the anesthesia is changed to ni trous oxide, succinylcholine chloride and norepinephrine drip, and this drip is continued into the postoperative period However in our experi ence, in most instances dramatic changes in the blood pressure do not occur

THYROIDECTOMY

Although rare children may have an adenoma, hyperplasia, or carci noma of the thyroid In instances of hyperthyroidism they are treated with propylthiouracil and iodine until the pulse rate decreases and the metabolism is reduced Rarely do these children have thyrotoxic heart disease

Hyperthyroid children are given slightly more than the normal premedi cation Anesthesia is induced with a thiobarbiturate, and intubation is performed after the administration of succinylcholine chloride A large sand pillow placed under the shoulders and lower neck provides good exposure of the gland The table is tilted in slight reverse Trendelenburg position Anesthesia is maintained with intravenous thiobarbiturate opiate, and nitrous oxide

These patients are monitored continuously with an electronic thermometer and kept cool by lowering the temperature of the operating room, while any elevation of body temperature is reversed quickly by placing the patient on ice bags The heart also is monitored by an electrocardiograph, and any marked tachycardia is reduced by further lowering of the body temperature Extubation follows the application of the dressing The anesthesiologist then examines the vocal cords to determine whether there is adduction paralysis of them from injury to the recurrent laryngeal nerve

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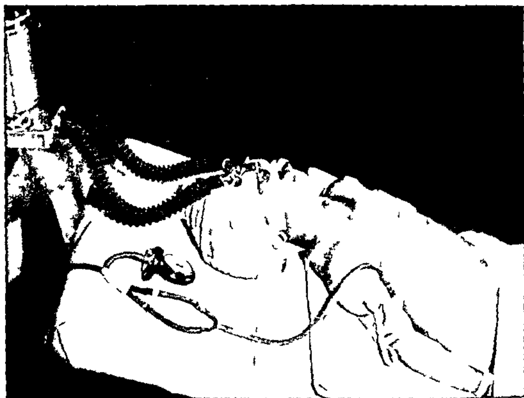


Fig 189 A child in a slight reversed Trendelenburg position preparatory to excision of a thyroglossal sinus and cyst

PARATHYROIDECTOMY FOR HYPERPARATHYROIDISM

When hyperparathyroidism is caused by an adenoma or diffuse para thyroid hyperplasia the treatment is surgical removal of the affected gland Fluids are forced preoperatively and the intake of milk restricted because the serum calcium is usually increased in such a patient If this increase in serum calcium is associated with impaired renal function and generalized loss of calcium from the bones (so-called "osteitis fibrosa), there may be a deposition of calcium in many parts of the body, the most injurious to the patient being calcinosis in the kidney

During surgery these patients are monitored by a continuous electro cardiogram to detect the onset of hypocalcemia which is in fact a relative hyperkalemia and intravenous calcium gluconate may be required to sustain myocardial tone and cardiac output The anesthesia is the same as that used for thyroidectomy

The postoperative course of the patient is observed carefully with particular attention paid to any indications of paralysis of the vocal cords or subglottic edema Any signs of tetany are corrected with intravenous in

jection of calcium gluconate The patient is put on a diet high in calcium, phosphorus, and vitamin D

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CHAPTER 25

OPERATIONS ON THE NERVOUS SYSTEM

The anesthetic management for neurosurgical operations is one of the most difficult and hazardous encountered by the pediatric anesthesiologist chiefly because of the effect of the disease on the general condition of the patient, the tremendous blood loss which can occur, and the position of the patient to facilitate surgery the latter may handicap the anesthesiologist in the management of both the respiratory and the cardiovascular systems

This chapter will include first, an outline of the basic requirements for the major cranial operations and second a discussion of the common neurosurgical procedures in infants and children remarking upon any variation from the basic technic set forth for major cranial operations

BASIC ANESTHETIC MANAGEMENT FOR MAJOR CRANIAL OPERATIONS

In evaluating the infant or child for major cranial operations, the anesthesiologist must be cognizant of the fact that the neurological disease may cause electrolyte fluid nutritional and vitamin imbalance, hyperventilation or hypoventilation, paralysis of some part of the respiratory mechanism, bradycardia tachycardia, hypotension or hypertension, convulsions, and unconsciousness any one of which may interfere with the safe management of the anesthesia

In preparing the conscious patient no solid food is allowed for eight hours preoperatively but clear sweetened fluids are given orally until two hours prior to operation

Premedication in conscious patients consists of scopolamine intramuscularly and a barbiturate suppository rectally, whereas in unconscious patients scopolamine alone is given

A cut-down (Fig 190) is done, or two 18 gauge styletted intravenous

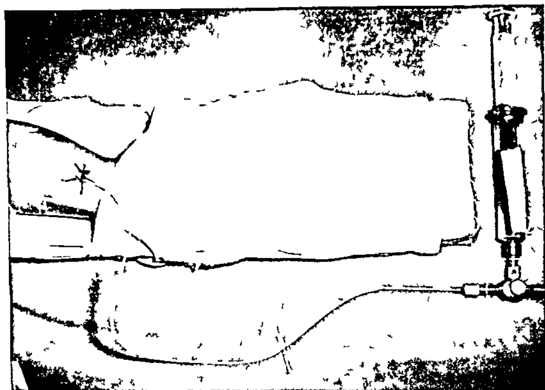


Fig 190 A cut-down with a polyethylene tubing inserted into the saphenous vein at the ankle There is also a three way stopcock through which blood can be injected rapidly

needles are inserted prior to anesthesia One to 4 liters of cross-matched blood should be available for use The usual precordial stethoscope, blood pressure cuff, and finger plethysmograph are applied Clipping and shaving of the child's hair may require intravenous quiescent doses of thiobarbiturate, in which case oxygen by bag and mask should be available

Induction of anesthesia is accomplished with intravenous thiobarbiturate followed by 0 5 to 1 0 mg/kg of body weight of succinylcholine chloride to facilitate intubation A wire-coiled nonkinkable, endotracheal tube is usually used The endotracheal tube is joined to the infant or adult circle filter (Fig 191), unidirectional valve (Fig 192), or T-tube (Fig 193) The tube is very securely strapped to the face, and the eyes are protected by 5 per cent boric acid ointment, closed lids, and a soft pad

Monitors, including a rectal or esophageal thermometer and an elec-

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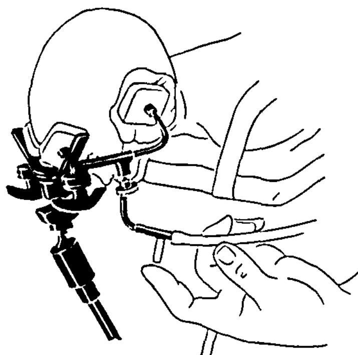


Fig 193 For this craniotomy, the T tube is employed and the anesthesiologist intermittently places his finger over the open arm of the T tube to ventilate the lungs

trocardiogram, are now attached Anesthesia is maintained with nonflammable and nonexplosive anesthetic agents such as nitrous oxide and oxygen, plus additional small doses of thiobarbiturate and succinylcholine chloride

Alternate anesthetic methods for cranial operations include nitrous oxide and Fluothane by semiclosed circle filter, suggested only for the skilled, cautious, and alert anesthesiologist to use on healthy patients in prone or supine position, and nitrous oxide with trichlorethylene by nonrebreathing technic, supplemented by intravenous thiobarbiturate or meperidine (Demerol) and succinylcholine chloride Respiration is usually controlled manually or mechanically (Fig 194)

Hypothermia to 31° C may be an aid in some operations such as excision of craniopharyngiomas or vascular tumors to reduce hemorrhage and to protect the vital centers from the damage of ischemic hypoxia In small infants having intracranial operations, however the room temperature is raised to 23 9° C (75° F), and they are placed on a warm-water mattress heated to 40° C (104° F), to maintain their body temperature at normal and prevent an apnea at the end of anesthesia

After anesthesia is established by a suitable technic, the patient is placed in the appropriate position by the surgeon, care being taken that no pres-

Fig 191 An infant positioned for drainage of a subdural hematoma A precordial stethoscope blood pressure cuff cut down in the right saphenous vein, and ECG are attached

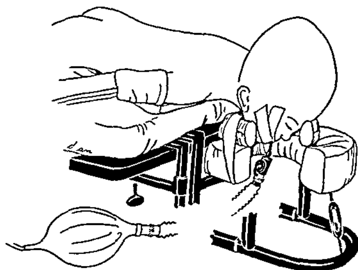


Fig 192 A diagrammatic sketch of a patient in position for craniotomy The head is supported in a headrest part of which is cut away to show the Fink nonrebreathing valve



Fig 195 The Kurze Johnson modification of the Gardner bucket for posterior fossa exploration in the upright position Anesthesia is maintained with the nonre breathing valvular technic with a spiral embedded gum rubber endotracheal tube in place Attached to the patient are a saphenous cut down in the right ankle rectal thermometer ECG leads a blood pressure cuff and precordial stethoscope

is removed It is desirable to have neurosurgical patients as free of anesthetic agent as possible at the end of operation, to distinguish between postoperative cerebral edema and the lingering effects of the anesthesia

The postoperative care of a neurosurgical patient requires the combined efforts of the surgeon anesthesiologist, and pediatrician Slow, gentle transfer directly to the bed is accomplished the child usually being postured in lateral or semiprone position with slight Trendelenburg if still unconscious Sometimes, if a large tumor has been removed with the danger of postoperative hemorrhage or increased intracranial pressure from cerebral edema mild reverse Trendelenburg posture or mild hypothermia of 34° C for one or two days is necessary During the subsequent period of unconsciousness the patient is turned from one side to another almost hourly to help prevent atelectasis In addition intermittent positive pres-



Fig 194 During removal of a brain tumor the lungs are being mechanically ventilated with a Bennett ventilator attached to the circle filter On the right hand side of the picture can be seen the anesthesiologist s hand squeezing the bulb of a blood transfusion set

sure can damage the patient's eyes or various superficial nerves, and that no impedance to respiration exists from posture In our hospital in the difficult upright position a small chair or the Gardner bucket modified by Kurze and Johnson holds the child while rubber clamps firmly fix the head to metal supports (Fig 195) The blood pressure is taken often during positioning to detect postural hypotension promptly treated with analeptics Such postural hypotension is sometimes prevented by binding the legs with elastic bandages and placing a firm pad against the abdomen

During operation supportive therapy entails continuously replacing the estimated blood loss by whole blood and calcium gluconate 10 per cent, 50 to 100 mg per 100 ml of blood given

At the end of operation and anesthesia, after the child is replaced in the supine position pharyngeal and endotracheal suction is performed, when the child is well oxygenated breathing adequately and preferably coughing, moving or showing other arousal signs the endotracheal tube

OPERATIONS ON THE STRUCTURES OVERLYING THE MENINGES, BRAIN, AND SPINAL CORD

Reduction of Fracture of the Skull

Compound fractures of the skull are treated early by debridement to minimize any existing infection. Hemorrhagic shock is remedied by blood transfusion before commencement of anesthesia.

Preanesthetic medication, anesthetic management, and blood replacement are similar to that described for cranial operations (p. 398).

Decompression of the Skull in the Newborn

Birth trauma may cause simple depressed skull fracture with indentation in the newborn. Usually the infant shows no signs or symptoms of brain damage, but elevation of the fracture is undertaken. No premedication is necessary. Since blood loss is minimal, no cut down is necessary. The patient is usually postured in the supine position, and the neurosurgeon makes a small incision close to the depressed fracture, through which he inserts an elevator beneath the fracture.

Anesthetic management is similar to that described for cranial operations (p. 398), but thiobarbiturate, if used, is given rectally, and succinylcholine chloride is given intramuscularly.

Craniectomy or Cranioplasty

Craniosynostosis, or premature closure of the sutures of the skull, results *in deformities of the head and frequently in damage to the brain and* eyes. Surgical repair is undertaken as soon as the diagnosis is made, usually during the first year of life, and consists of cutting sections out of the skull along the prematurely closed suture to permit normal enlargement of the brain.

Since hemorrhage is usually profuse, a preoperative cut-down using a large-bore cannula is essential. Scopolamine alone is adequate for premedication.

Anesthesia is induced and maintained in accordance with that outlined for cranial operations (p. 399). A straight endotracheal tube adapter affords a more convenient connection to a valvular apparatus or infant circle absorber.

The operation is usually performed with the patient in the prone posi-

sure breathing for ten minute periods about four times daily, tracheal aspirations, and intramuscular nikethamide (Coramine) may be helpful in preventing atelectasis

The child is often put in a cold, moist, oxygen enriched atmosphere to prevent development of laryngeal edema from several hours intubation, infants, however, with a tendency to apnea from hypothermia, are kept warm To prevent tracheal aspiration of stomach contents, a stomach tube is often inserted, left in place, and flushed out at intervals until consciousness returns It is used for feeding where paralysis or paresis of glossopharyngeal and vagus nerves has followed removal of acoustic neuroma and produced diminished laryngeal and glottic reflex sensitivity

Blood pressure, pulse, respiration, response to reflex stimuli, and equality in the size of the pupils are carefully studied Opiates are avoided since they may depress vital functions, especially respiration and blood pressure, moreover, opiates are not necessary for relief of pain in these patients Codeine with some barbiturate may be given for headache and restlessness after full consciousness returns

Fluids can generally be taken orally a few hours postoperatively or may be given in small amounts through the gastric tube Intravenous fluids are rarely necessary, furthermore, a slight oligemic state is desirable to prevent cerebral edema

The occurrence of a peripheral circulatory collapse and unconsciousness especially after operations near the third ventricle, has been described, and may be treated with an intravenous or intramuscular vasopressor

Pulmonary edema, seen typically following excision of tumors of the floor of the fourth ventricle or following operations for head injuries, may be treated with oxygen under slight positive pressure or by tracheostomy if it persists Tracheostomy may also be indicated for tracheobronchial suction and prevention of atelectasis if the patient is unconscious many days

Hyperpyrexia following intracranial operations is a grave sign, often indicating cerebrovascular thrombosis near the brain stem or thalamus, and is often resistant to treatment In such instances the patient is cooled in an oxygen tent Croupette, or by being placed on a cooling blanket

occur readily from lack of vasomotor tone Fortunately, complete compression of the spinal cord is rare in children

The kidney function of these paralyzed patients must be studied in particular, especially if the lesion is of long duration, since the decalcification of the bones may produce a calcinosis, often more marked in the pelvis of the kidney, a disease aggravated by a physiological obstruction caused by a cord bladder and the resultant infection

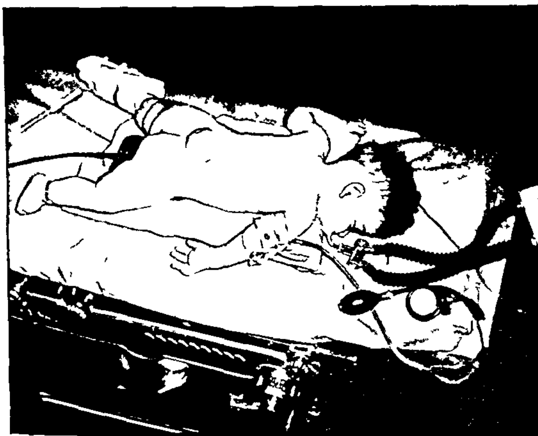


Fig 197 For repair of meningomyelocele the shoulders and pelvis are supported on bolsters The lungs are ventilated throughout the surgery by manual compression on the breathing bag There is a cut-down in the left ankle for the administration of blood or medications

Meningoceles having no nerve involvement, have none of these problems of paralysis but inasmuch as the danger of rupture of the meningocele with subsequent infection is imminent surgery is undertaken as soon as possible

The management of the anesthesia is similar to that for any cranial operation with the patient in the prone position (see p 398) with the exception that in these cases the anesthesiologist is at the head of the patient instead of being at one side (Fig 197)

tion and with his head immobilized in a headrest at the end of the operating table In this position, particular attention should be devoted to protection of the eyes so that there is no pressure on them (Fig 196)

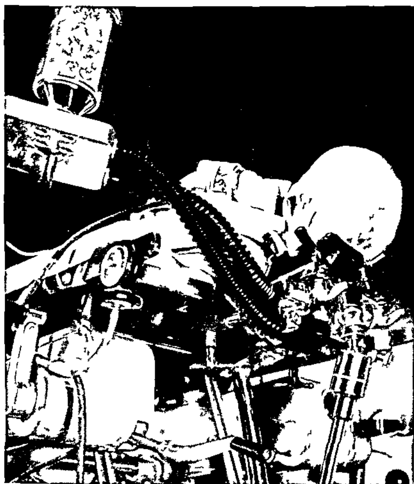


Fig 196 Prone position for cranioplasty with the head secured in a rest at the end of the operating table Bolsters are placed under each shoulder and the pelvis A right angle Rovenstine catheter connector joins the spiral embedded gum rubber endotracheal tube to the circle filter

Most fatalities in the operating room, during this operation, result from lack of realization of the tremendous blood loss and lack of adequate blood replacement

Repair of Spina Bifida with Meningocele or Meningomyelocele

There can be such multiplicity of complications in these cases that each child must be studied thoroughly by the anesthesiologist When the meningomyelocele is high in the cervical region there may be intercostal paralysis, as well as paralysis of the bladder and the intestine simulating a high spinal anesthetic In such an instance, postural hypotension can

A venipuncture with a styletted needle is desirable A small intravenous dosage of thiobarbiturate is given, followed by succinylcholine for intubation Anesthesia is maintained with trichlorethylene and nitrous oxide, employing a unidirectional valvular technic

Both lower extremities are wrapped with an elastic bandage from the ankles to the groin (Fig 198), and the patient is then placed in the up-

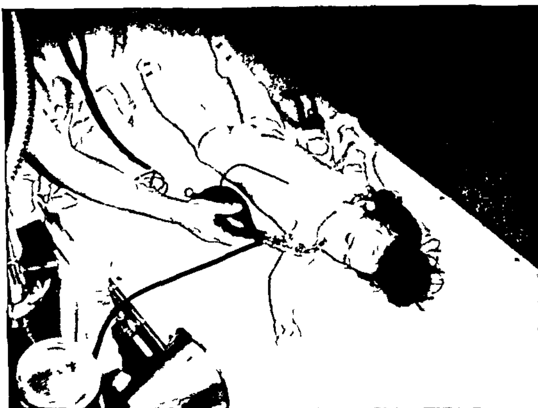


Fig. 198 In preparation for an encephalography this infant s legs are bound to keep more of the blood in the upper part of the body and thus offset the danger of hypotension when she is placed in the upright position

right position The blood pressure is taken to note any resulting postural hypotension relieved by administration of a vasopressor, but since anesthesia is minimal, the cardiovascular system of the patient can usually accommodate the change of position and no blood pressure change occurs

A lumbar puncture needle is inserted and the spinal fluid is replaced with air As this procedure continues usually pallor occurs Any decrease in intensity of the heart sounds, hypotension, or change in respiration may signify the onset of a serious complication, and in such instances, the patient should be placed immediately in Trendelenburg position, the lungs ventilated with oxygen, and a vasopressor administered intravenously

Following the application of dressings, the patient is turned to the supine position, and the postoperative care is in accordance with all cranial cases (p 402)

OPERATIONS ON THE MENINGES

Drainage of Subdural Abscess, Hematoma, and Hygroma

Before surgery, it is difficult to distinguish between an abscess hematoma, and hygroma These patients, however, are chronically ill and may have considerable compression of the brain tissue, with convulsions and vomiting the first indications of such pressure The anemia which frequently exists in these patients is treated by preoperative blood transfusions Preanesthetic medication is minimal because of the child s debility The surgeon may establish drainage through a trephine opening or turn a bone flap for the removal of the thicker-walled chronic membranes The patient is usually in the supine position Apart from the above the conduct of anesthesia follows the outline previously given for cranial operations (See p 398)

Ligation of the Meningeal Vessels

The middle meningeal artery may be torn in a fracture of the skull the symptoms being due to increased intracranial pressure The typical history is a period of unconsciousness followed by a lucid interval later succeeded by increasing lethargy and finally coma Prognosis in these cases is very often serious, since the patient s condition may be critical before surgery is undertaken These patients require only atropine or scopolamine for premedication, anesthesia being minimal doses of the agents usually employed for cranial operations (See p 398)

Encephalography

Encephalography or the introduction of air into the brain sinuses through a needle placed in the lumbar subarachnoid space, is performed to demonstrate any distortion enlargement, or displacement of the ventricles The patient may have a history of convulsions or retarded development In infants this procedure must be regarded seriously, since the upset in cerebral dynamics from the exchange of air and fluid can cause sudden death

Premedication is normally a reduced dosage of thiobarbiturate rectally combined with scopolamine intramuscularly

puncture needle, taped in place in the lumbar subarachnoid space, permits drainage of the spinal fluid and reduction of the size of the brain Before closure of the dura at the end of the operation the ventricular system may be again filled with sterile saline solution inserted through the spinal needle

Operations upon the base of the brain for ligation of an aneurysm or for the removal of a tumor present a more difficult surgical problem because of the vascularity and the inaccessibility of the region The surgery can be facilitated by using hypotensive drugs or the hypotension which accompanies hypothermia This hypothermia reduces the amount of anesthetic agent required, causes marked constriction of the blood vessels, increases the length of time that brain tissue can be deprived of its blood supply with impunity, allowing intermittent compression of the carotid arteries to prevent or control severe hemorrhage, and reduces cerebral edema

Ventriculocisternostomy

Patients scheduled for ventriculocisternostomy have usually congenital, sometimes acquired hydrocephalus The size and weight of the head vary tremendously, and it must be supported manually or by head clamps

All operations on these children are directed toward improved absorption of spinal fluid by shunting some from the ventricles into another absorptive area of the body By means of a polyethylene tube the spinal fluid from the ventricles is taken to the abdominal cavity, mastoid cells, or the superior vena cava

Most of these patients are debilitated and inactive and require one-half or less the normal premedication for their weight

Anesthesia consists of small doses of the usual agents used for cranial operations Soon after induction an electrocardiogram is attached since these patients have reduced cardiac reserve from inactivity and may develop hypotension with blood loss or with slight overdosage of anesthetic agent The electrocardiogram is also important if the catheter is to be inserted into the superior vena cava since inadvertent insertion into the right ventricle may cause cardiac irritability The location of the catheter is checked by means of a roentgenogram When the head is greatly increased in size the drainage of the spinal fluid may cause a sudden disproportion between the skull and the head clamps The anesthesiologist, therefore should be prepared to quickly adjust the equipment

At the moment of the filming the electrocardiogram should be turned

Anesthesia must be continued throughout the roentgenography, and the airway must be kept patent inasmuch as the patient is turned in many positions as the many skull films are taken

At the end of the procedure, respiration and circulation may be depressed Nikethamide (Coramine), 25 per cent, 1 to 5 ml, may be administered intravenously in order to arouse the patient, but the pallor and lethargic conditions may remain for some time in spite of the fact that sedative drugs have been minimal

OPERATIONS ON THE BRAIN

Ventriculography

Ventriculography usually replaces encephalography when increased intracranial pressure is suggested by history and by physical examination It is done in the upright position It is advisable to have cross matched blood available, since occasionally the trephine may cause severe hemorrhage

Premedication and anesthetic management are similar to that outlined for encephalography (See p 408)

Air is injected into the ventricles for their visualization by roentgenography If the films demonstrate displacement, distortion, or dilatation of the ventricles by a mass, exploratory craniotomy is usually performed immediately

The neurosurgeon remains near the patient throughout since a sharp increase in intracranial pressure, signified by slow pulse, rising blood pressure, and apnea, can occur If these signs develop the ventricles are tapped immediately to reduce the increasing intracranial pressure because herniation of the brain may occur

Drainage of Abscesses, Cysts, or Neoplasms, Removal of Neoplasms

In operations upon the cerebellum in the upright or prone position where the neck is flexed acutely for adequate exposure there is grave danger of a kinking of the endotracheal tube The management of these cases is the same as that for any cranial operation with two exceptions First, the maintenance of spontaneous respiration is highly desirable in cerebellar explorations because of the proximity of the respiratory centers, and a sudden apnea enables the anesthesiologist to warn the surgeon of his interference with the vital regions Second in operations for tumors at the base of the brain where the approach is difficult, a malleable, lumbar

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off to avoid damage to its stylus and the precordial stethoscope should be removed to prevent obscuring the situation of the catheter in the superior vena cava. Following removal of the endotracheal tube the patient must be moved gently to bed and observed closely, as following other intracranial surgical operations (See p 403)

OPERATIONS ON THE SPINAL CORD AND NERVE ROOTS

Excision of Neoplasms or Cysts, Evacuation of Hematoma, Drainage of Abscess, Removal of Foreign Body

The evaluation of the patient and the management of the anesthesia for these operations is similar to that previously described for repair of spina bifida (See p 406)

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groups (1) intraocular, and (2) extraocular and operations on the accessory organs of the eye, since the selection of anesthetic agent and technic is for the most part dependent upon this distinction

INTRAOCULAR OPERATIONS

Goniotomy (Incision of Capsule of the Lens), Suture of Eyeball, Removal of Foreign Body, Operations for Glaucoma—Iridotomy, Iridectomy, Iridomesodialysis (Freeing of Adhesions of the Iris), Discission (Needling of the Lens), Capsulotomy, Retina Reattachment

In these open-eye operations the possibility of losing the vitreous and probably the sight of the eye is of foremost concern to the anesthesiologist In this respect coughing, vomiting straining sneezing, or laryngospasm must be prevented since any one of them is likely to increase intraocular pressure and result in spilling of the vitreous In an elective open-eye operation if the patient has a cough the operation should be postponed

Although some surgeons use phenylephrine (Neo synephrine) to produce a bloodless operative field, most of them use the more effective drug, epinephrine, in which case anesthetic agents compatible with epinephrine must be used Nevertheless there are many methods of anesthesia suitable for open-eye surgery and any of the following anesthetic agents and technics may be employed

Tribromoethanol, Nitrous Oxide, Muscle Relaxant, and Endotracheal Intubation The night before surgery the patient is given an enema to prevent evacuation at the time of the rectal instillation of tribromoethanol Clear fluids are given up to two hours before anesthesia Preanesthetic medication in the form of scopolamine is given one hour before the rectal instillation of the tribromoethanol The amount of tribromoethanol, 3 per cent solution instilled is seldom less than 100 mg/kg of body weight except in obese children

When the patient is unconscious, oxygen is administered by bag and mask A muscle relaxant gallamine (Flaxedil) or d tubocurarine, is given intravenously or intramuscularly after which the patient is intubated with the angle piece of the endotracheal tube pointing caudad because the anesthesiologist sits at the side of the patient while the surgeons sit at the head of the patient With the angle piece of the endotracheal tube connected to an infant or adult circle filter the patient s lungs are ventilated manually or mechanically with a nitrous oxide-oxygen mixture

The medicant, atropine drops epinephrine or phenylephrine (Neo-

CHAPTER 26

OPERATIONS ON THE ORGANS OF SPECIAL SENSE (EYE AND EAR)

OPERATIONS ON THE EYE

Because of increasing awareness that ultimate visual and psychological effects may be considerable in the child suffering from an eye defect, corrective eye operations are being performed on patients in early childhood Consequently, anesthesia for these operations has become a very important branch of pediatric anesthesiology

In preparing a child for an eye operation, it is explained to him that his eyes will be bandaged following the operation for such an explanation promotes his cooperation during the postoperative period which should be as restful as possible to ensure a satisfactory recovery The customary critical preanesthetic evaluation of the patient is just as essential before an eye operation as before any other operation Although patients with congenital eye defects seldom have associated anomalies of other systems of the body a history, physical examination hemogram and urinalysis should be done for other diseases may be present Moreover, since most ophthalmic operations are elective the results of the preanesthetic evaluation may render advisable the postponement of the operation so that necessary corrective measures may be instituted For example an elective eye operation would be postponed if upper respiratory infection were discovered or if the hemoglobin values indicated the presence of anemia Many cases of nutritional anemia can be treated by proper diet

In the following discussion, operations on the eye are divided into two

dine (Demerol) one hour before anesthesia. A styletted needle is inserted into a vein on the back of the hand of the patient which will be closest to the anesthesiologist during the operation, and then this arm is usually splinted. Often cyclopropane is administered to dilate the veins and facilitate the cannulation.

Through the intravenous needle, thiobarbiturate is administered, followed by gallamine (Flaxedil) or d tubocurarine. The patient is oxygenated with a bag and mask, and when his muscles are relaxed he is intubated.

The cardiovascular system is monitored and the blood pressure is recorded. A rise in blood pressure is an indication of lightening of the anesthesia, and fractional dosages of thiobarbiturate and gallamine (Flaxedil) are administered when such a rise occurs. Throughout the surgery, the respiration is artificially controlled. Spontaneous respirations soon return at the close of surgery, but intercostal paresis, if present, is corrected with neostigmine (Prostigmin) or edrophonium chloride (Tensilon).

The postanesthetic management of the patient is the same as that following tribromoethanol and intubation, however, here the patient regains consciousness somewhat sooner than the one who has been given tribromoethanol.

Thiobarbiturate Rectally, Nitrous Oxide, Muscle Relaxant, and Endotracheal Intubation. Thiobarbiturate, 10 per cent, is sometimes given rectally to the infant or child. The preparation of the patient is the same as for the one who receives intravenous thiobarbiturate.

A muscle relaxant is administered intravenously, and the patient is oxygenated. After spraying the vocal cords with a local anesthetic, intubation is performed. Then nitrous oxide and oxygen are administered, using an infant circle filter, with respirations being controlled manually or mechanically. Spontaneous respiration is usually resumed at the close of surgery, at which time the patient is extubated.

Again, intercostal paresis or lag, if present, is corrected with Prostigmin or Tensilon, but with such light anesthesia as provided by this method, seldom is there any prolonged intercostal paresis.

The rest of the postanesthetic management is the same as that described above for the other anesthetic technics for open-eye surgery.

Thiobarbiturate Rectally and Nitrous Oxide Insufflation. Although rectal thiobarbiturate and insufflation of nitrous oxide are recommended by some anesthesiologists, we believe that the risk of laryngospasm and sneezing with consequent possible loss of vitreous which accompanies this technic makes it an inadvisable one for open eye operations.

synephrine), used to dilate the pupils is instilled in the eyes by the surgeon with one eye being treated first and then the other, to avoid a high blood concentration of the drug, which has such a pronounced systemic effect The operative field is then prepared with germicidals Throughout the surgery, the heart is monitored with the precordial stethoscope and finger plethysmograph, and the blood pressure recorded

At the end of the surgery, spontaneous respiration is soon resumed, and the patient is extubated At this time, his arms are splinted, after which he is transferred to the bucket or carrier, placed on his side, and taken to the recovery room When settled in his bed, the splints are secured to *the sides of the bed to prevent him from tampering with the eye dressings*

He often requires prolonged attention inasmuch as consciousness returns slowly Since a reposeful postoperative course is a principal objective, the child is comforted by reminding him again that his eyes will be bandaged for some time, and, at the same time, reassuring him that someone will be near to him at all times At times, sedatives may be required to keep the child peaceful and still Another helpful measure is for the nurse to apply a cold compress on the patient's nose, since the opiates in the premedication often produce an irritation of the nose In most cases, the compress will help prevent the patient from attempting to rub his nose

One objection to the foregoing method of anesthesia for these open eye operations is the possibility of postanesthetic laryngeal edema and hoarseness following the endotracheal intubation which, in turn, might make the patient cough and become restless, not a desirable condition following an ophthalmic operation If there is any indication of subglottic edema, the *patient is placed in cold, moist atmosphere*

Tribromoethanol and Nitrous Oxide Insufflation This technic differs from the one above only in that muscle relaxant and intubation are omitted Instead nitrous oxide and oxygen are insufflated through the nipple of a Waters' oropharyngeal airway Since this method does not afford the anesthesiologist the same degree of control of the anesthesia as does the endotracheal intubation method the anesthesia may wane before the surgery is completed unless an incremental dosage of tribromoethanol one half the initial quantity is given rectally

This method of anesthesia is favored by most surgeons, since the possible postanesthetic complications which follow endotracheal intubation are avoided

Thiobarbiturate Intravenously, Muscle Relaxant, and Endotracheal Intubation With this technic the patient is given scopolamine and meperi-

who have undergone open-eye operations, since relatively lighter preanesthetic medication is given and lighter stages of anesthesia are practicable throughout the surgery The postanesthetic care of the patient is similar to that for the patient following intraocular operation, with the emphasis on assuring a peaceful quiet recovery period

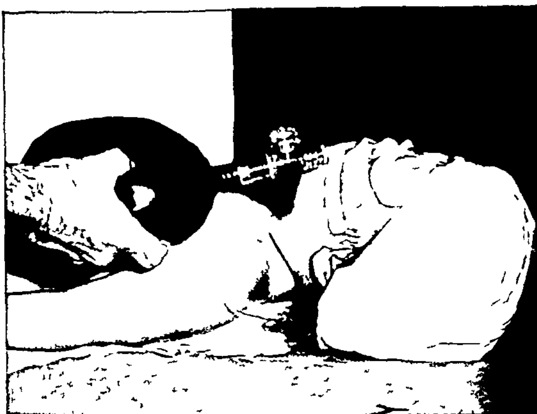


Fig 199 A patient after an eye muscle operation with the oral endotracheal tube and the unidirectional valve still in place For the surgery she had been given intravenously meperidine (Demerol) a small dose of thiobarbiturate and d tubo curarine

OPERATIONS ON THE EAR

MYRINGOTOMY, INCISION OF FURUNCLE OF EAR, OTOSCOPY, REMOVAL OF FOREIGN BODY IN EXTERNAL AUDITORY CANAL

Of the above operations the most frequently performed one in infants and children is myringotomy for otitis media In the preanesthetic evaluation of the patient consideration must be given to the fact that otitis media often follows upper respiratory infection with accompanying high temperature With such characteristics as high temperature and dehydration,

EXTRAOCULAR OPERATIONS AND OPERATIONS ON THE ACCESSORY ORGANS OF THE EYE

Examination of Fundus, Measurement of Tension, and Refraction

These three closed-eye operations are generally brief procedures, and are managed without the advantages of control of anesthesia afforded by endotracheal intubation The patient is therefore prepared with heavy sedation in order to keep him motionless during the surgery, since light planes of anesthesia are used, particularly is this so when the selected method is nitrous oxide anesthesia

The choice of anesthetic agents depends upon the drug to be used by the surgeon to dilate the pupils If phenylephrine (Neo-synephrine) is to be used for this purpose, cyclopropane or Fluothane anesthesia is employed On the other hand if epinephrine drops are to be used nitrous oxide and oxygen anesthesia is the choice Anesthesia for these operations is carried on by means of an infant circle filter absorption technic, and respiration is controlled manually throughout the procedure

Enucleation, Recession and Cinching or Advancement of the Ocular Muscles, Excision of Orbital Tumor, Excision of Meibomian Glands (Chalazion), Blepharoplasty (Plastic Repair of the Lids), Probing of Lacrimonasal Duct

The above extraocular and accessory eye organ operations are of long duration Following the preanesthetic evaluation of the patient, he is prepared with heavy preanesthetic medication For operations on the extraocular muscles, the scopolamine dosage is larger than normal, to offset the oculocardiac reflex slowing of the heart which is induced by traction on these eye muscles

Since the vasopressors used by the surgeon for dilating the pupils are usually instilled after induction of anesthesia, cyclopropane can be used for the induction A styletted needle is inserted into a vein and meperidine (Demerol) 1 mg/kg of body weight, is given slowly, intravenously, and then succinylcholine chloride is given intravenously to facilitate intubation With the endotracheal tube connected to a circle filter or unidirectional valve, anesthesia is maintained with occasional small doses of succinylcholine chloride together with nitrous oxide and oxygen Assisted or controlled breathing is carried on throughout (Fig 199)

Postoperatively these patients are not nearly as depressed as those

MASTOIDECTOMY

Although mastoidectomy is seen infrequently by the pediatric anesthesiologist now that antibiotics are used extensively, occasionally the bacteria are resistant to antibiotics and a simple or radical mastoidectomy becomes inevitable. If the infant or child has been ill for several days before the mastoidectomy, he should be given intravenous fluids, and possibly blood transfusion for any existing anemia. Premedication is generally a combination of opiate, barbiturate, and scopolamine, in reduced amounts if the child is toxic.

As a rule, a nonexplosive, nonflammable technic is necessary because the surgeon uses a drill or cautery, and the use of cyclopropane, trichlorethylene, or Fluothane is usually precluded because he also employs epinephrine. Therefore, anesthesia is induced with meperidine (Demerol), 1 mg/kg of body weight, and intravenous thiobarbiturate, and the patient is intubated with the aid of succinylcholine chloride. A straight adapter is attached to the endotracheal tube, and circle absorption technic employed, with the anesthesiologist facing the patient on the side of the patient's head opposite to that of the surgeon. Anesthesia is maintained with nitrous oxide supplemented by occasional small doses of thiobarbiturate and rarely, additional small doses of meperidine (Demerol) or succinylcholine chloride. Very small amounts of the anesthetic agents are required except for the incision and suturing of the skin, which are the most painful parts of the procedure.

In bilateral mastoidectomy, after the surgery on one ear is completed the head of the patient is turned to his other shoulder. In order to keep the surgeon in close proximity to the nurse and the instruments, the table can be turned end for end, or instead of turning the operating table which entails changing the location of the anesthetic machine, a curved angle piece can be interposed between the straight endotracheal tube connector and the circle apparatus. The disadvantage to the latter procedure is that the patient's face is directed away from the anesthesiologist so that he does not have constant visualization of the face when the surgeon is operating in the vicinity of the facial nerve.

Postoperatively, these patients make a rapid recovery with minimal nausea and vomiting. Following bilateral mastoidectomy, some subglottic edema from a long period of intubation may necessitate placing the patient in cold moist atmosphere.

these patients are particularly susceptible to convulsions, in addition the anesthesia is often performed with the mask technic which because of the added dead space frequently fails to remove all the carbon dioxide in the inspired air Low concentrations of carbon dioxide, even as low as 1 or 2 per cent, are an additional impetus to convulsions These convulsions usually occur within five minutes of the induction of anesthesia

Because of this likelihood of convulsions, it is advisable to premedicate the patient scheduled for myringotomy with a barbiturate as well as scopolamine If the patient has been without fluids for some hours and has a high temperature and rapid pulse intravenous fluids should be administered prior to surgery a precaution which also may prevent convulsions *during the anesthesia Moreover, through the same intravenous needle,* small doses of thiobarbiturate may be administered, another measure to avoid convulsions

In addition to these precautions, if the anesthesiologist is using the mask technic he should employ a very high flow of gases in fact, several liters and he should also employ manual ventilation of the lungs in order to avoid any respiratory acidosis By using a circulator, in which the gases are kept in constant circulation by a mechanical pump, manual compression of the breathing bag enables the anesthesiologist to reduce the high supply of gases since the mask is emptied continuously

Preanesthetic medication for the operations listed above, other than myringotomy, is the standard premedication in accordance with the weight and physical status of the patient

For any of these operations cyclopropane and oxygen or nitrous oxide and Fluothane by means of the unidirectional valvular or circle absorption technic may be used also satisfactory are nitrous oxide and trichlorethylene with the unidirectional valvular technic The patient is intubated for we have found that some of these procedures especially removal of a foreign body in the external auditory canal, can be of long duration and the anesthesiologist must be prepared to maintain complete control of the anesthesia for these extended periods

Anesthetic complications following these operations are rare but the usual antibiotic treatment for infections and continued fluid therapy for the dehydration and acidosis particularly following myringotomy for acute otitis media are carried out As following all operations in which endotracheal intubation has played a part incidence of subglottic edema must be detected early and treated

CHAPTER 27

MANAGEMENT OF ANESTHESIA FOR OPERATIONS UPON THE PREMATURE AND NEWBORN INFANT

Remembering always that the balance is delicate between life and death in the premature and newborn infant, the pediatric anesthesiologist never strays from certain essential principles in the care and management of these infants, consequently, he prevents infection, controls body temperature, regulates fluids and electrolytes in the operating room and avoids damage by anesthetic agents, technics, and high concentrations of oxygen

Although this chapter is limited to a discussion of the management of anesthesia during the operative and postoperative periods, attention is directed to the characteristics of prematurity as outlined in Chapter 1 (p 7), for the preanesthetic evaluation of these infants is an integral part of the management of the anesthesia

Already handicapped by disease engrafted upon immaturity of all the systems of their bodies these infants are not equipped to combat infection Therefore the anesthesiologist when in communication with these infants faithfully complies with the sterile precautions exercised in the nursery

The infant s body temperature is regulated at all times because he is unable to stabilize his body temperature For instance, he is transported to and from the operating room in a warm incubator in which the temperature ranges from 32° to 37° C and this temperature range is duplicated as closely as possible in the operating room In addition the operating table is covered with a large warm-water mattress, the water within being

TYMPANOPLASTY

Following chronic infection of the middle ear, in many instances the eardrum may be destroyed In this case tympanoplasty is performed to reconstruct the eardrum, using the adjacent tissue lining the canal.

The management of the anesthesia for tympanoplasty is the same as that outlined for mastoidectomy (p 421)

OTOPLASTY

Otoplasty is usually done for the correction of protruding or underdeveloped ears or for construction of an ear in the event of congenital absence of an ear Infants and children with these abnormalities are usually in good physical condition when presented for this elective surgery, but have a psychological complication because of the anomaly Therefore heavy premedication consisting of a barbiturate, opiate, and scopolamine is used to overcome this mental state In other respects the anesthetic management is essentially the same as that described for mastoidectomy

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There is an above average likelihood of overloading a small infant with fluids, inasmuch as he is unable to concentrate the urine and faces difficulty in the excretion of sodium and chloride In most instances, he requires neither blood nor fluids during the operation However, in the premature, any blood lost is replaced, but this is merely a temporary remedial measure as he quickly returns to his typical anemic state, then again in the newborn, there are times when the extensiveness of the surgery may necessitate the administration of blood to compensate for the amount lost

In considering anesthetic agents for these infants, the anesthesiologist should abide by one steadfast rule, that is, to use only minimal amounts of any selected medication or anesthetic agent Because of lethargy, irregularity of respiration, and over all immaturity of the respiratory system of the premature infant and the newborn infant up to one week of age, no sedatives are given to them, and because of the lack of secretions, no belladonna derivates are needed

Whenever possible, the operation is performed under local anesthesia, with a minimal amount of anesthetic agent being employed In other instances, the procedure is accomplished under nitrous oxide-cyclopropane anesthesia, using a nonrebreathing technic The nitrous oxide is given to avoid the damage which may be caused by sustained high concentrations of oxygen although it is recognized that there are occasions when indications of hypoxia may preclude the use of nitrous oxide

In the majority of cases, the infant is not intubated because laryngospasm is a very rare complication in this age group Nevertheless there are some operations such as extensive intrathoracic or intra-abdominal ones in which endotracheal intubation provides the safest conditions for the patient In these cases, a sterile endotracheal tube, from 4 to 4 6 mm external diameter (No 12 to 14 French), is inserted while the infant is either awake or under cyclopropane anesthesia One or two spare sterile endotracheal tubes should be on hand for in prolonged operations the tiny endotracheal tube may become blocked and have to be replaced immediately Because of the immaturity of the respiratory centers, especially in the premature infant, he is given the least possible amount of cyclopropane, for he may stop breathing with very small administrations of the anesthetic agent Should apnea occur pressure is applied sufficient only to overcome the resistance to airflow through the lumen of the small endotracheal tube As a further safety measure in these very delicate infants, an instant to instant picture of the patient s condition is provided by

40° C Then on top of this mattress is placed a dry towel (Fig 200) Throughout the course of anesthesia, the infant's temperature is monitored with a continuous-recording rectal thermometer, and any alteration in his temperature provokes immediate action to restore it to the desired level



Fig 200 On arrival in the operating room the infant is lifted from an incubator and placed on a warm water mattress The thermometer at the bottom of the picture records the rectal temperature continuously during surgery

If there is indrawing of the intercostal spaces, cyanosis of the tips of the digits, rapid pulse and respiration, rales in the chest, then tracheal aspiration two or three times a day is necessary As well, nikethamide (Coramine), intramuscularly, in 0 5 ml doses, every two hours is given, and low pressure (to 20 cm of water) positive pressure breathing for five to ten minutes at a time, four or five times daily, is applied In the resistant case, low pressure positive pressure breathing may be done through an endotracheal tube A crying squirming or restless infant, absence of cyanosis in the fingers and toes and minimal indrawing of the intercostal spaces are signs indicating clearance of the atelectasis

In reviewing the characteristics of these premature and newborn infants, it is apparent that unrelenting maintenance of the efficiency of the respiratory system of these infants by the anesthesiologist, pediatrician, and surgeon is of prime concern before, during and after the operation

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means of an electrocardiograph or other monitor as well as the routine precordial stethoscope

The infant should be moving by the termination of the surgery He is lifted gently from the operating table and placed in the lateral position in a warm humidified, and oxygenated incubator (Fig 201) for the return trip to the nursery where the meticulous sterile regime is continued

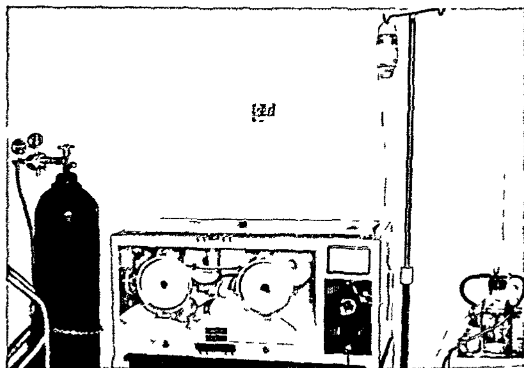


Fig 201 Newborn infant postoperatively in the lateral position in an incubator

Of utmost importance in the postoperative care of premature and new born infants *is that they be under the constant vigilance of a specially* trained nurse In the first place, since the gag reflex is weak in the imma ture infant, the aspiration of food is comparatively unrestrained, and the possibility of this complication occurring renders indispensable strict ob servation of the infant after feeding is resumed Another risk is the infant s tendency to stop breathing with the slightest provocation such as turning or feeding but immediate detection of cessation of breathing accompanied by immediate stimulation of the infant is generally sufficient to reinitiate respiration An even greater danger is the insidious onset of atelectasis at first in an undiagnosable degree then in an hour or so progressing to a massive, sometimes irremediable atelectasis with cyanosis To prevent this occurrence of massive atelectasis the infant should be encouraged to cry

RESPIRATORY COMPLICATIONS

Obstruction from Secretions, Blood, or Gastric Contents

Obstruction in the pharynx and trachea from secretions, blood or gastric contents can be prevented or alleviated by posturing the emerging patient in the lateral Trendelenburg position, with his head extended, his mandible pushed forward and his mouth open Secretions will, in this way, drain out of the mouth and nose These secretions also may be aspirated out of the mouth by the anesthesiologist

The greater hazard of the patient aspirating solid food into his trachea, when anesthesia has to be administered for emergency surgery, can be avoided by leaving the endotracheal tube in place until after vomiting is finished Only when the patient s reflexes are very active and he is almost conscious is he finally extubated

Laryngospasm

Another common cause of respiratory obstruction on emergence from anesthesia is partial or complete laryngospasm, either upon withdrawal of an endotracheal tube or upon lightening of the anesthesia If an endotracheal tube is in position, the lungs are filled with a high concentration of oxygen and then the tube is gently withdrawn during exhalation, administering oxygen by mask immediately thereafter as a supplementary safeguard These measures will usually prevent hypoxia occurring from temporary laryngospasm Postponing removal of the endotracheal tube until the infant or child has active reflexes and is bucking on the tube will frequently prevent laryngospasm

Should laryngospasm occur, it is treated with oxygen by mask under steadily increasing pressure In the rare severe, prolonged case of laryngospasm, a small dose of succinylcholine chloride, 1 0 mg/kg of body weight, intramuscularly or intravenously may be necessary to break the spasm and prevent hypoxia with adequate oxygenation and ventilation being maintained until normal breathing is re-established

Laryngeal (Subglottic) Edema

If laryngeal edema occurs from an endotracheal tube, its location is subglottic opposite the cricoid cartilage and its presence is usually evident within one-half to one hour after extubation Generally prompt treatment in a cold atmosphere enriched with oxygen and high humidity, will gradu-

CHAPTER 28

POSTANESTHETIC CARE

Mortality statistics must in truth include deaths occurring during the postanesthetic period; unfortunately many a patient's life has been lost from inadequate attention and treatment during the postanesthetic period.

The necessity for integrating the over-all condition of the patient with the study of the patient's condition as a result of the anesthetic and surgical procedure is just as essential in the postanesthetic period as before or during the operation. Therefore, when caring for the patient after the anesthesia, the anesthesiologist must be aware of and take into consideration the treatment of the patient by the surgeon and pediatrician, such as the resumption of a particular treatment for a disease unrelated to the surgical procedure, since the disease itself may give rise to serious complications or aggravate existing ones. This cooperative management of the patient postoperatively is demonstrated by the fact that the anesthesiologist often makes one or more visits to the patient in the company of the pediatrician or surgeon, as well as making his individual visits. Also, an integral part of the postanesthetic care is that carried out by the recovery room nurse; her constant vigilance, skill, and willingness and ability to carry out treatment are essential to a successful outcome for the patient.

The following discussion covers the prevention and treatment of those postanesthetic complications which particularly concern the pediatric anesthesiologist.

treated by artificial ventilation of the lungs, using the Pulmonator (Fig 202) In our experience, there is no specific antidote for the combined barbiturate-opiate depression of respiration One of the most helpful antidotes is nikethamide (Coramine), which can be given intravenously or

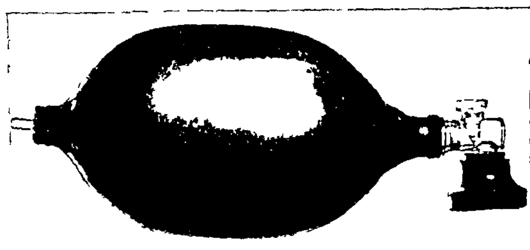


Fig 202 Pulmonator A modified Lewis Leigh valve is connected to the mask On compressing the bag the lungs are inflated with air On releasing the bag it expands causing air to flow into it through the unidirectional valve at the tail of the bag.

intramuscularly every two hours until the patient is able to assume adequate spontaneous respiration

Depression of Respiration by Muscle Relaxants

The basic treatment for muscle relaxant apnea is pulmonary ventilation, manual or mechanical, until the child breathes spontaneously If mild but inadequate respiratory efforts are present after d tubocurarine has been used Tensilon, 10 mg, or Prostigmin, 1 to 5 mg depending on age preceded by intravenous atropine, often causes a dramatic increase in depth, rate, and adequacy of respiration There is not, however, a specific antidote for succinylcholine chloride, although fresh blood, calcium, Tensilon, and intravenous fluids have been used for this purpose

Worthy of note is the fact that we have not seen a severe apnea of over five to ten minutes' duration since we have given smaller doses of succinylcholine chloride intermittently when required rather than by the continuous drip method With the continuous drip technic, there is a tendency to give larger doses of succinylcholine chloride, and even though this might not cause postanesthetic apnea, it might produce a residual

ally relieve the edema over a twelve- to twenty four-hour period A Croupette which supplies cold, saturated oxygenated atmosphere or a cold steam room is used The temperature of the Croupette or room should be from 20° to 21 1° C (68° to 70° F), the atmosphere should be saturated with moisture (tested by a hygrometer), and the oxygen concentration should be no more than 40 per cent (verified by an oxygen analyzer) A continuous-recording rectal thermometer should be inserted in the patient If such treatment is not effective, the patient is placed on an ice water mattress (Fig. 203, p 433)

Laryngeal edema, being a partial respiratory obstruction, encourages atelectasis, and therefore the edema must be treated early A serious laryngeal edema requires constant observation and attention by the anesthesiologist For instance particularly in infants and young children he may have to perform tracheal aspirations three or four times during a twenty four-hour period

In rare cases where the edema is unnoticed until advanced, or there is a complication such as paralysis of one vocal cord, a tracheostomy may be performed to cure the laryngeal obstruction However, we have had only four patients tracheostomized during twenty-five years of intubation in infants and children, and with our present knowledge and experience, we question whether any of these four tracheostomies were actually necessary

Depression of Respiration by Preanesthetic Medications

Since barbiturates opiates and tranquilizers are used freely in premedication and can depress respiration postanesthetically the dosages of these drugs should be kept to a minimum Also, since it is common practice to administer opiates and thiobarbiturates intravenously throughout the operation one must consider that the cumulative effect of these drugs may be a rather severe postanesthetic depression

In the event that any of these drugs has produced a noticeable depression of respiration, certain antagonistic drugs may be helpful For example depression of respiration by opiates can often be overcome by n allylnormorphine (Nalline) or levallorphan tartrate (Lorfan) These antagonists are injected until respiration is sufficient for adequate oxygenation If the drug depression is severe oxygen therapy may be required Fortunately, depression of respiration by opiates is not usually prolonged Then again seldom are we confronted with depression of respiration attributable solely to opiates, for the opiates are ordinarily combined with barbiturates in the premedication Therefore the depression of respiration may have to be

Such a complication should be prevented by maintaining the patient's normal body temperature throughout the anesthetic procedure, accomplished by raising the temperature of the operating room and resting the infant on a mattress containing water heated to normal body temperature The temperature of the water in the mattress is kept constant by continuous circulation through coils (Fig 203)

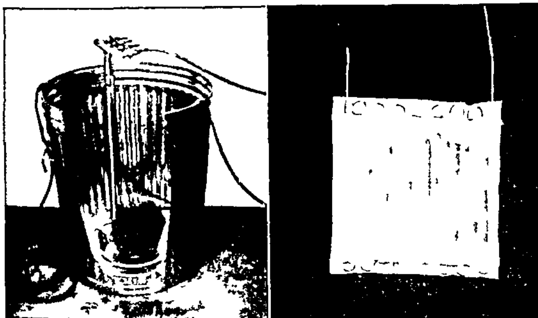


Fig 203 Thermonator a unit for controlling the body temperature of a patient *(Left)* Container for water and a circulating pump The water is pumped to the mattress on the right through one of the attached plastic tubes and then returns to the container by the other tube *(Right)* Cooling or heating mattress with embedded plastic coils through which water circulates (Western Anesthesia Equipment Co Redwood City California)

Atelectasis

One of the most severe respiratory complications is atelectasis Its causes are manifold, with any one of the following shouldering or sharing the responsibility for its occurrence inadequate expansion of the alveoli in the newborn, muscular weakness from a pre-existing disease, surgical procedure anesthetic agents or muscle relaxants, engorgement of the lungs with blood from congenital heart disease, residual atelectasis of the lungs from intrathoracic operations or partial chronic obstruction to respiration —each one of which causes a reduced tidal volume and it is this reduced tidal volume which causes an incipient collapse of small sections of the lung

In children, ventilatory insufficiency especially inadequate tidal volume,

paresis of the muscles of respiration similar to that seen following d tubocurarine If depression of respiration does occur postoperatively, artificial respiration is used until the patient's regular breathing is established This artificial respiration can be carried out by one of the many devices available, such as the Pulmonator, or the Bird, Bennett, or Jefferson ventilators Considerable guidance can be provided in these cases by observing carefully the expansion of the thorax and the continuous recording carbon dioxide analyzer

Depression of Respiration by Anesthetic Agents

Even though some of the inhalation anesthetic agents cause a depression of respiration, it is usually of exceedingly short duration because the gases are eliminated rapidly from the patient s system For example, there may be instances of short periods of respiratory depression following the use of cyclopropane or trichlorethylene, but this depression is overcome before the patient leaves the operating room by applying artificial respiration for a short period of time

A more severe complication is that caused by the cessation of the administration of ether or cessation of the stimulating surgery, producing a hypoventilation by leaving the patient to the mercy of the previously administered hypnotic drugs

Habit Apnea

Of frequent occurrence in the operating room is so called habit apnea, which is a period of apnea seldom lasting more than five minutes following the cessation of the administration of the anesthetic agents but this apnea, on occasion is prolonged by the depressant drugs which have been administered It follows a period of controlled respiration, and even though the patient may have a high alveolar carbon dioxide spontaneous breathing is not resumed

Recovery from habit apnea is usually spontaneous, and the patient rapidly resumes respiration with rapid return of reflexes However, should this apnea be prolonged intravenous nikethamide (Coramine) 250 to 1250 mg, depending on the age of the patient will generally provide the necessary stimulus to start normal breathing

Depression of Respiration by Reduction in Body Temperature

Occasionally, small infants whose body temperature has fallen in the operating room may need to be warmed almost to normal before adequate respiration is established

8 Stop passing the catheter if difficulty in passage is encountered oxygenate the patient, using bag and mask before making another attempt

9 Suction trachea briefly, since prolonged suctioning causes unrelenting coughing and severe hypoxia

10 Oxygenate patient on withdrawing tracheal suction catheter

11 Take the blood pressure

12 Pass suction catheter again if necessary

13 Stop the procedure if severe bradycardia occurs, oxygenate the patient and check the blood pressure

Pneumothorax

Pneumothorax, a rare complication occurs particularly in newborn infants It may be spontaneous as a result of the infant s own violent efforts to fully expand his partially atelectatic lungs, it may be created by the anesthesiologist while he is artificially ventilating the lungs, or it may be created by the surgeon during certain thoracic operations such as tracheo-esophageal fistula repair or diaphragmatic hernia repair

If the pneumothorax is causing hypoxia hypercarbia, or circulatory depression as a result of a misplaced heart, it is necessary to aspirate the air or apply underwater seal drainage

CARDIOVASCULAR COMPLICATIONS

Patients who have either congenital or acquired cardiac disease may have many cardiac complications following operation most of them being alterations in rhythm or rate of the heart, and are treated by the cardiologist There are however other cardiovascular complications which can occur in any patient after anesthesia and in such cases the care is largely the responsibility of the surgeon and anesthesiologist

Certain cardiovascular complications such as hypotension hypertension rarely cardiac arrhythmias and cardiac arrest may occur during the immediate postanesthetic recovery period The cardiovascular monitors used during anesthesia—the precordial stethoscope the blood pressure cuff, the finger plethysmograph, and in some cases the electrocardiograph and carbon dioxide analyzer—are left attached until all the storminess of emergence from anesthesia is past and the infant or child is considered fit to be sent to the recovery room, where the monitoring of blood pressure and pulse rate is continued Also, if the anesthesiologist determines that fluids blood or drugs may be needed during the postanesthetic period he will leave in place the cut down or styletted intravenous needle used during the operation

is seldom sustained since they can cough move actively, and take deep breaths In some infants, however, who can neither cough nor cry, sustained hypoventilation can occur An indrawing of the lower or upper intercostal spaces on inspiration, or an indrawing or lag in elevation of one side of the thorax on inspiration calls for prompt efforts to induce coughing Nikethamide (Coramine), tracheal aspiration, or a five minute period of intermittent, positive pressure breathing will often eliminate this incipient atelectasis But if the cause of the hypoventilation is still present that is, obstruction to respiration or depression of respiration, then incipient atelectasis can reappear in an hour or so, and the treatment to promote coughing and thus improve the tidal volume must be repeated

In untreated cases, the minor degrees of atelectasis progress and soon involve large areas of the lungs The temperature, pulse rate and respiratory rate become elevated, cyanosis appears but can be relieved by high concentrations of oxygen, and breath sounds become distant over the affected areas Confirmatory evidence is a film of the chest which will show large areas of atelectasis Undaunted by the fact that such advanced and extensive atelectasis in the infant is, in most instances, resistant to treatment by nikethamide (Coramine), tracheal aspiration, increased humidity, and/or intermittent positive pressure breathing the anesthesiologist, nevertheless must assiduously pursue this course of treatment since survival of the patient is dependent upon it

Procedure for Tracheal Aspiration Tracheal aspiration for relief of atelectasis is attendant with the possible complications of trauma or acute hypoxia but the occurrence of these complications can be minimized by adopting the following procedure for tracheal aspiration

1 Have available the following equipment

a Bag mask laryngoscope suction apparatus, and firm stiff suction catheters

b Oxygen supply

2 Wait four to five hours after a meal before commencing tracheal aspiration

3 Check blood pressure Patients with low blood pressure do not tolerate this procedure well

4 Attach precordial stethoscope

5 Restrain the patient by bundling him in a sheet

6 Oxygenate the patient using bag and mask since cardiac vagal reflex is more severe in the presence of hypoxia

7 Perform laryngoscopy and gently pass suction catheter into the trachea, while the patient is held firmly by the nurse or assistant

anesthesia excessively tight bandages around neck, chest, or abdomen, and gastric dilatation from ingested air Some of these conditions when present in a moderately healthy patient may prove uneventful, but in a weak, sickly, debilitated infant or child may be rapidly fatal

If cardiac arrest or ventricular fibrillation occurs it must be treated forthwith by ventilation with high oxygen effective cardiac massage, and administration of stimulatory, vasopressor, or antifibrillatory drugs, as the situation warrants

NERVOUS SYSTEM COMPLICATIONS

Failure to Regain Consciousness

Failure to regain consciousness in an infant or child who has not undergone neurosurgery or who has not had large sedative doses of opiates or barbiturates is seen most frequently following cardiac arrest in the operating room If following cardiac arrest, the patient has roving eyeballs small pupils pupils that react to light or he responds to pain by movement of the hands or legs, then the prognosis is usually favorable Nevertheless, any patient who has suffered cardiac arrest on the operating table should have his body temperature cooled to around 33° C for two or three days postoperatively This reduction in temperature helps prevent the occurrence of cerebral edema which can cause considerably more brain damage than that caused by the hypoxia in the operating room

To reduce the body temperature rapidly, the patient is covered with chipped ice and then wrapped in a coiled cooling mattress (see Fig 203, p 433) When the patient s temperature is reduced to about 33° C it is maintained at this level by means of the ice water circulating through the plastic tubing in the mattress

After cardiac arrest some patients have tetanic convulsions and go into opisthotonus but these tetanic spasms tend to disappear as the patient's condition improves But if the pupils remain fixed and there appears to be no gradual improvement in the patient s condition in the first forty-eight hours postoperatively, the prognosis is exceedingly grave

Convulsions

Convulsions even though a rare postanesthetic complication, may arise as a result of any of the following idiopathic epilepsy brain tumor or scar cerebrovascular accident water intoxication high body temperature, acidosis, or dehydration Those convulsions with a central nervous system

Hypotension

Hypotension during emergence from anesthesia may result from depressed respiration, bucking, coughing, laryngospasm, cessation of anesthesia, blood loss without adequate replacement during operation, hypothermia, or sudden rough movements of the patient. This hypotension may tip the precarious balance in an ill infant or child.

In most infants and children, hypotension is accompanied by a rapid pulse, although some infants will show a slow pulse. If the blood pressure is low, the recovery room nurse promptly consults the anesthesiologist, who treats the hypotension with enriched oxygen atmosphere, Trendelenburg posture, abdominal binder, elastic bandages on the legs, and blood replacement.

Hypertension

The occurrence of hypertension in a patient in the recovery room is rare. If seen postanesthetically, it can generally be concluded that it was present before anesthesia as a result of kidney disease, coarctation of the aorta, endocrine disease, or essential hypertension. Therapy, in this event, is directed toward the specific disease.

Hypertension in a patient recovering from a brain operation, especially if accompanied by a slow pulse, may be a grave omen of increasing intracranial pressure, and in this case the anesthesiologist consults the neurosurgeon, who may want to remove fluid from the ventricle.

Changes in Rhythm or Rate of the Heart

Cardiac irregularities are often due to a short period of hypoxia or carbon dioxide excess and may be remedied spontaneously with oxygen therapy. On the other hand, persistent tachycardias or irregularities deserve an electrocardiogram and the concerned attention of a cardiologist, who will diagnose and treat them before more serious consequences such as cardiac failure, cardiac arrest, and ventricular fibrillation occur.

Cardiac arrest or ventricular fibrillation occurring in the operating room during emergence from anesthesia may have many contributory causes, for this is a period fraught with sudden changes, and any of these changes may disturb the delicately balanced body mechanisms which are already impaired by the insults of anesthesia and surgery. It therefore behooves the conscientious anesthesiologist to protect the patient from all possible dangers, such as hypoxia, carbon dioxide excess, rough movements, deep

anesthesia, excessively tight bandages around neck, chest, or abdomen, and gastric dilatation from ingested air Some of these conditions when present in a moderately healthy patient may prove uneventful but in a weak, sickly, debilitated infant or child may be rapidly fatal

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origin can be prevented or at least obtunded with adequate barbiturates or anticonvulsant drugs in the preanesthetic medication, while most of those with another origin can be avoided by not permitting the cause to develop

If convulsions occur, treatment is oxygen inhalation, intravenous thio barbiturate, and specific treatment of the particular cause

Nerve Injuries

Seldom are postanesthetic neuropathies seen in pediatric anesthesiology, perhaps because of the young patient s liberal distribution of sub cutaneous fat which protects the nerves Occasionally, however a foot drop is seen usually due to a tightly attached splint Brachial plexus palsy is practically unknown in pediatric practice On one occasion, we saw a child with a strabismus following general anesthesia, however, this cleared in a day or two and may have had an emotional basis

Pain

With most infants and children postanesthetic pain is seldom severe enough to warrant analgesics or sedatives Should pain become unbearable *morphine 0 75 mg/yr of age, or meperidine (Demerol), 0 5 mg/kg* of body weight, may be given with good effect

UROGENITAL COMPLICATIONS

The commonest renal complication in infants and children is the retention of urine A full bladder not only is uncomfortable but also predisposes the patient to urinary reflux and infection Seldom is catheterization necessary in the conscious infant or child, but may be required if bladder distention persists in the unconscious infant or child

TRAUMATIC COMPLICATIONS

Protecting the infant or child from injury is an essential element of postanesthetic care In the first place a check of the child s teeth is advisable to assure that none have been inadvertently chipped or removed by the laryngoscope airway, or mouth gag If any are missing they must be either found or the child s chest x rayed to ensure that the tooth is not in his lung If by ill chance he has aspirated into his lungs the missing tooth removal of it as soon as possible by the endoscopist is naturally a requisite of good medical care

Traumatic complications are an ever present hazard as the infant or

child is rousing Unless guarded at every moment, he may tumble from the operating table or stretcher and suffer injury He may scratch his skin or his eyes, tear off bandages, or investigate his surgical wound

Trauma is still a hazard in the recovery room as the patient emerges into a state of full consciousness Until conscious, the infant is prevented from falling by his incubator sides and top or by the crib sides, while the older child is restrained within the compass of his bed by barred sides If the child thrashes about his arms and legs may be secured to the bed side by restraints but if this is done, the child should be in the lateral or prone position to prevent aspiration of any vomitus The special form padded arm restraints applied to a child after an eye operation to prevent him from removing the eye bandages, are left in place until a state of consciousness and reasonable quietude is regained

TEMPERATURE

The temperature of the infant or child is recorded by the recovery room nurse immediately upon his arrival in the recovery room and frequently thereafter A low body temperature not deliberately induced in the operating room is seen frequently in infants up to one month of age, especially in premature infants and in infants who have undergone prolonged abdominal or central nervous system operations Since infants with a low body temperature may breathe indifferently or not at all unless stimulated and warmed they are usually treated with nikethamide (Coramine) intermittently, 0 5 to 1 0 ml and warmed in an incubator

On the other hand, a distinctly elevated temperature, seen more frequently in children than in infants, can be equally deleterious and must be remedied by using minimal covering, sponge baths, cold-water mattress or ice bags, and oxygen tent

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